U.S. Mines, Bur. of

Technical Paper 106

DEPARTMENT OF THE INTERIOR

FRANKLIN K. LANE, SECRETARY

BUREAU OF MINES

VAN. H. MANNING, DIRECTOR

ASPHYXIATION FROM BLAST-FURNACE GAS

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no 106

ENGINEERING

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BY

FREDERICK H. WILLCOX

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First edition. October, 1916.

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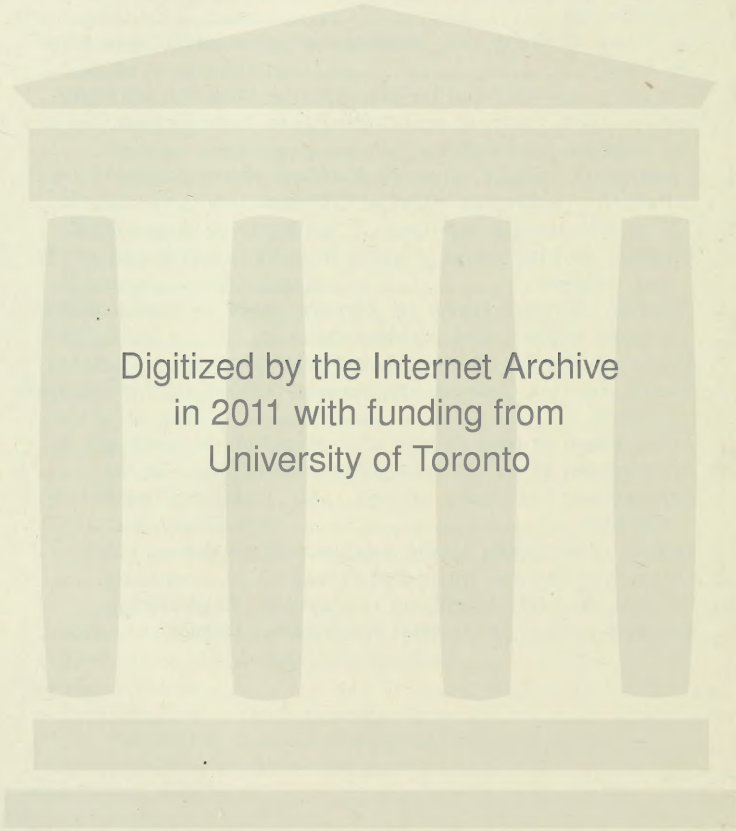
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ASPHYXIATION FROM BLAST-FURNACE GAS.

By Frederick H. Willcox.

INTRODUCTION.

This report is issued by the Bureau of Mines in pursuance of its endeavors to increase safety and efficiency in metallurgical industries. It discusses the nature and causes of poisoning from blast-furnace gas, itemizes the places where gas may be expected to be encountered, suggests safeguards and points out the precautions to be taken in working about gaseous places. Acknowledgment is hereby made to companies who have extended the opportunity of examining their plants and furnished information in regard to their practice.

Blast-furnace gas is peculiar in that it is very poisonous and under certain conditions, as when it has been cleaned, is without color or odor by which it may be detected. Gas is practically always present about the top and bottom of the furnaces, frequently in such small proportion that it is not evident to the physical senses, but at the same time in sufficient volume to cause asphyxiation if breathed for 20 or 30 minutes. Proportions sufficient to cause asphyxiation or gassing also occur with more or less frequency all along the route of the gas (figs. 1 and 2), at the stoves and boilers when they are taken off for cleaning or repairs, inside of gas mains, downcomers, and other parts of the gas-main system, at sand or goggle valves, and during repairs to the charging equipment and stock line. The increasing application of furnace gas to gas-driven blowers and generators has introduced additional equipment such as tower washers, fans, and other cleaning devices that also must be entered from time to time for cleaning and repairs. At all the above places there is always the possibility that gas may be present where the crews have to work, either from leakage, insufficient ventilation, or from emission of gas retained in the brickwork, flue dust, or deposits in the apparatus. Though poisoning by blast-furnace gas usually results in nothing more serious than illness and severe headache, it may cause unconsciousness and even death, and realization of the dangers and a strict observance of every precaution is essential in undertaking any work in an atmosphere contaminated by furnace gas, or in sending men into confined places, from which it would be difficult to escape, in proximity to material emitting gas or difficult to ventilate.

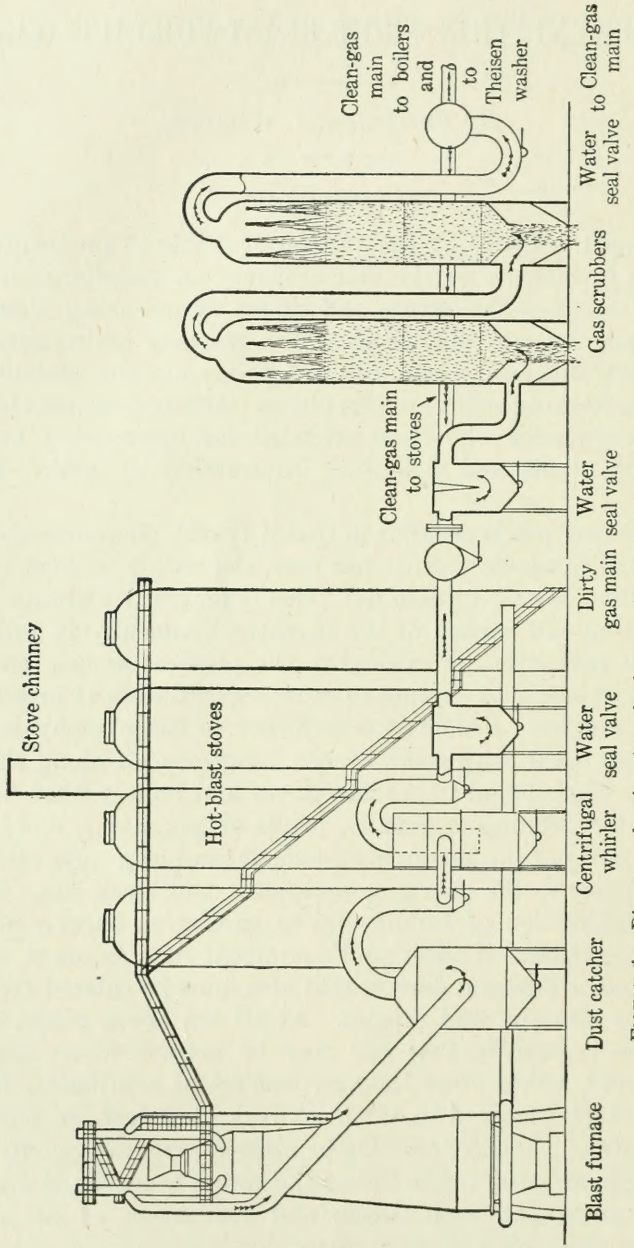

FIGURE 1.—Diagram showing travel of gases from blast furnace to stoves and washers.

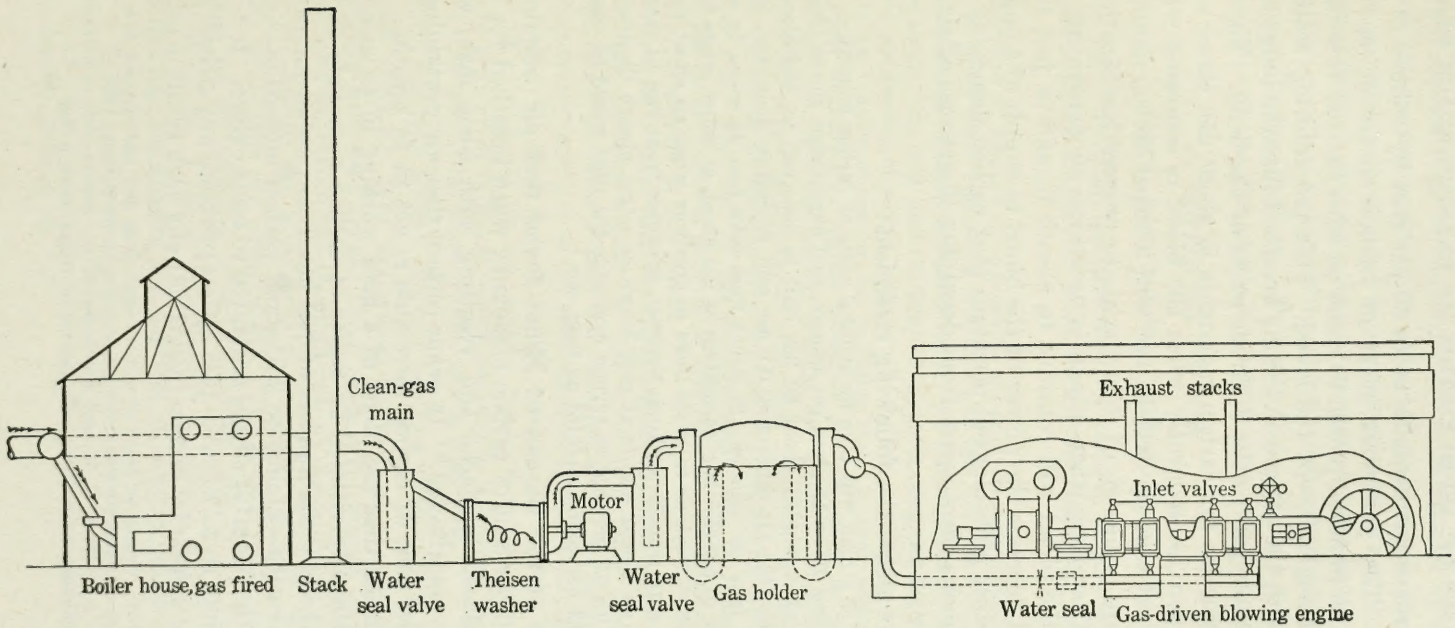

FIGURE 2.—Diagram showing travel of furnace gases to boiler house, Theisen washer, and blowing engine.

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CAUSES OF ASPHYXIATION BY BLAST-FURNACE GAS.

Blast-furnace gas contains 20 to 30 per cent by volume of carbon monoxide. The poisonous effect of carbon monoxide on man is caused by its peculiar power to combine with the red coloring matter—the hemoglobin—of the blood. This red coloring matter also combines with the oxygen in the air breathed into the lungs and distributes the oxygen to the different parts of the body. The affinity of the corpuscles for carbon monoxide is about 250 times as great as for oxygen; consequently when the blood is saturated with this gas it will not take up oxygen, nor will it expel carbon monoxide so long as there is enough of it in the air to prevent combination with oxygen. Therefore, when a man is breathing air containing carbon monoxide the blood will continue to absorb it, and in just that degree it will decrease the power of the blood to supply the body with oxygen. Most physiologists maintain that carbon monoxide has no other poisonous effect apart from depriving the tissues of the necessary supply of oxygen.

Haldane[a] makes the following statement:

> The blood of a man will take up about 2 pints of carbon monoxide. A man at rest breathes 10 or 12 pints per minute, and experiment shows that of the carbon monoxide inhaled about 60 per cent is absorbed by the blood. If a man would breathe air containing 0.1 per cent of carbon monoxide, he would absorb 0.007 pint per minute. It would then take him 2¾ hours to absorb a whole pint or to produce half saturation of the blood, at which stage his limbs would become so weak as to cause them to give way when an effort was made to walk. A man who is working, however, breathes from two to three times as much air as a man who is at rest, hence he might absorb the pint within an hour. With 0.2 per cent of carbon monoxide the time would be one-half as long; with 0.3 per cent, one-third as long, etc.

Members of the Bureau of Mines found that air containing as little as 0.10 per cent of carbon monoxide, when breathed for several hours, produced headache and vomiting with some men, whereas others were not affected.[b] It seems certain that air containing more than 0.05 per cent of carbon monoxide is not fit to breathe. It has been established that the blood of a man working in an atmosphere that is continually vitiated by traces of carbon monoxide undergoes a change whereby the number of red blood corpuscles increase, and greater toleration—ability to withstand carbon monoxide—is established and the harmful effects mitigated to some extent. It is a subject of dispute as to whether this action prevents any dehabilitating effect on the system by carbon monoxide; any such result is rather an

[a] Haldane, J. S., Causes of death in colliery explosions and underground fires: Report to the Secretary of State for the Home Department, Great Britain, 1906.

[b] Burrell, G. A., Seibert, F. M., and Robertson, I. W., Relative effects of carbon monoxide on small animals: Tech. Paper 62, Bureau of Mines, 1914, p. 19.

occupational disease than an accident and is mentioned as affording one cause of the greater resistivity displayed by some men than others. In no case can such toleration of carbon monoxide be established in a man's system that he can work in an atmosphere containing 0.20 per cent of carbon monoxide, equivalent to 0.80 per cent of blast-furnace gas, without suffering ill effects. Probably toleration can not be established for proportions greater than 0.05 per cent carbon monoxide.

DETECTION OF GAS.

TESTS FOR CARBON MONOXIDE.

Methods for detecting the presence of carbon monoxide are described in Technical Paper 11, from which the following extract[a] is taken.

> The author has by the aid of a portable gas-analysis apparatus made tests of the air in mines after explosions and fires and has thus ascertained on the spot the composition of the atmosphere in the workings. Because of the time required to make such tests and the need of a person with some knowledge of gas-analysis apparatus, chemical tests * * * are not made as often as they should be. Another reason for omitting them is that quick chemical tests for small quantities of carbon monoxide are not made as successfully as chemical tests for methane, carbon dioxide, and oxygen. Perhaps the best chemical test for carbon monoxide, in that other gases do not interfere and very simple apparatus is required, is by the use of blood diluted with water to a buff-yellow tint. This test, in the author's experience, is capable of distinctly showing as little as 0.03 per cent of carbon monoxide in the atmosphere. The method of procedure is as follows:
>
> One or two drops of blood from the finger are diluted with water until equal portions of the solutions placed in 100 c. c. test tubes have a buff-yellow color; one of the tubes is taken into the mine, and at the place where the air is to be tested about 50 c. c. of the blood solution is poured out, the mine air taking its place. The tube is then corked, taken to the surface, and gently shaken for 10 minutes. If the air contains carbon monoxide, the pink color caused by the presence of carbon monoxide hemoglobin is detected by comparing the solution with the normal blood solution in the other tube.

Palladium chloride gives a distinct reaction with carbon monoxide and is used abroad.[b] The apparatus consists of a protected glass tube provided with two cocks; these cocks are opened and the gas to be examined is introduced through one of them by a rubber bulb until the air filling the apparatus is expelled through the second cock. The two cocks are then closed. The second cock is provided with means of introducing a strip of filter paper saturated with palladium chloride. Carbon monoxide if present darkens the paper, the more quickly the higher the content of carbon monoxide. The

[a] Burrell, G. A., The use of mice and birds for detecting carbon monoxide after mine fires and explosions: Tech. Paper 11, Bureau of Mines, 1912, p. 8.

[b] Breyre, A., Review of accidents by asphyxiation in Belgium during 1906–1911: Ann. des Mines de Belgique, 1912, pp. 65, t. 17.

amount can be roughly approximated by the time interval, as shown in the table following:

Time required for reaction with carbon monoxide.

Volume of CO.	Reaction visible.	Time required for paper to become completely darkened.
Per cent.	*Min. sec.*	*Minutes.*
0.01	17 ..	60
0.10	1 ..	9
0.25	44	6
0.75	.. 20	3
1.00	.. 16	2
2.00	.. 15	2

These methods of testing for carbon monoxide may be used to detect traces of furnace gas in mains, scrubbers, or other confined places before sending men into them for repairs or cleaning, and whenever there is any uncertainty as to whether the place is free from gas this test should be employed.

Canaries will show distinct distress in an atmosphere containing as small a proportion as 0.15 per cent[a] of carbon monoxide.

DETECTION OF GAS BY COLOR OR ODOR.

Gas may be detected by its color, which is due to impalpable fume, or by the odor, due to traces of volatilized cyanide, tars, and amides or other organic compounds, provided it has not been washed. Partly washed gas is usually slightly odorous and may be visible because of mist or fume. Gas that has been thoroughly washed has at times neither color nor odor by which it may be detected and is more poisonous because the gas has, to some extent, been concentrated by cooling. The gas that escapes about the bosh has a particularly reeking odor, and traces of it impart a pronounced odor to the atmosphere; also that above the mantle, where it may escape through openings for cooling-plate connections, has a very pronounced odor. There is no certainty that gas may always be detected in the many places where it may escape or where it is necessary to work in proximity to it. At times a faint odor may indicate dangerous quantities, sufficient to cause unconsciousness in five minutes, whereas at other times as strong an odor may be perceptible in an atmosphere containing but a trace of the gas. Too much depends upon the character of the gas, whether it has been confined or cleaned, its origin, and on the persons concerned, to place any reliance on evidence appealing to the senses, nor can

[a] Burrell, G. A., The use of mice and birds for detecting carbon monoxide after mine fires and explosions: Tech. Paper 11, Bureau of Mines, 1912, p. 11; Burrell, G. A., Seibert, F. M., and Robertson, I. W., Relative effects of carbon monoxide on small animals; Tech. Paper 62, Bureau of Mines, 1914, p. 12.

any reliable rule or direction be made in regard to working in gaseous air except to keep out of it if it is either smelled, seen, or suspected, unless the proper precautions are taken.

SYMPTOMS OF POISONING.

Absolutely no reliance can be placed in warning symptoms of gas poisoning for two reasons: First, they may not occur; second, if they do occur, they may precede collapse by so brief an interval that the person has not time to escape from the gaseous air. A man may have been working in air containing such a small proportion of gas that he feels no discomfort. If he then enters air containing a larger proportion, or if the proportion of gas unexpectedly and suddenly increases, he may because of the partly saturated condition of his blood quickly become unconscious; also the realization of the presence of gas by some symptom will usually lead to sudden exertion with deeper breathing, which may, under certain circumstances, quickly result in loss of consciousness, while the victim is still in the gaseous atmosphere. Furthermore the symptoms are at times indefinite and men differ greatly in susceptibility to gas poisoning; often collapse is not preceded by much distress or pain. Some of the preliminary symptoms are dimness of sight, weakness of limbs, dizziness, stiff neck, slight choking, or nausea. For some time after recovery, there may be severe headache, nausea, pneumonia, or epileptic seizures.

PLACES OF DANGER.

The places where gas may usually be expected, the causes of gas leaks or presence of gas, and the precautions to be taken are described in the following pages.

BOSH AND MANTLE.

The usual type of bronze cooling plate and banded bosh is never gas tight, and it is impossible to make it tight. The bosh is continually leaking more or less, depending to some extent on the working of the furnace. Jacketed or plate boshes may be tight when built, and in the early part of the blast, but are apt to develop leaks later on; moreover they are not satisfactory for many classes of ore or coke or for certain grades of iron. The gas leaking from the plate boxes or arches, brick joints, and interstices, or openings in the riveted or bolted bosh jacket segments, sweeps up the bosh and, accumulating under the mantle, rises between the bustle pipe and mantle, in proximity to the usual location of the waste-water trough, circle or water-supply pipe, and three-way cocks. Gas is also encountered when it becomes necessary to change a plate and often is especially troublesome in working on the higher rows. The men in

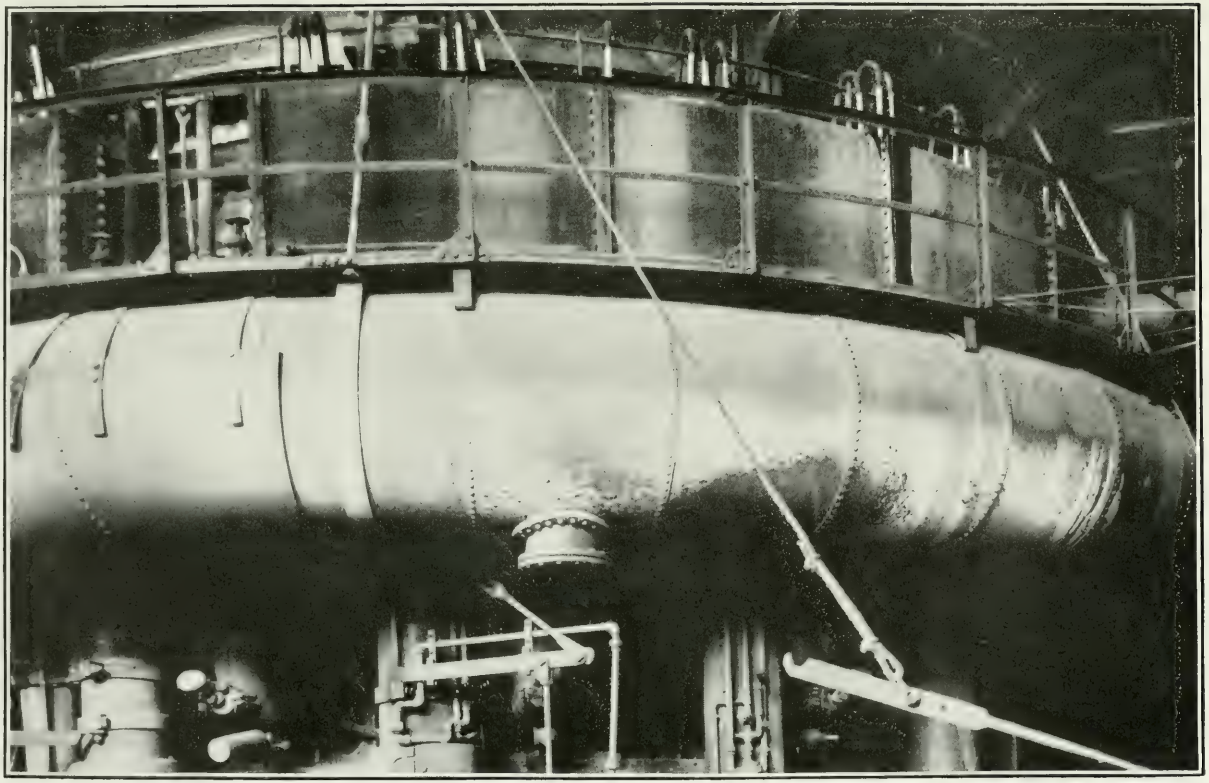
the pipe-fitting gang are often cramped between the bustle pipe and bosh, and subject to whatever accumulation of gas there may be in that vicinity, occasionally in excessive amount and of an especially rich and poisonous nature and usually of rank odor. The presence of gas at this point of the furnace must be accepted as one of the minor and infrequent hazards of furnace work, and on that account needs to be kept in mind and all precautions and care exercised while working there.

ACCIDENTS ON THE BUSTLE PIPE.

In at least three instances men have been fatally overcome on bustle pipes. One man was found lying on a bustle-pipe platform dead. In another case a stove tender inspecting water discharges was partly overcome and fell from the bustle pipe with fatal results. In the third case one of the cast-house crew attempted to bring a man, who had been partly overcome, down a ladder from the bustle pipe and let him fall. Two instances are known of pipe fitters who were fatally overcome while working on the piping about the furnace. The number of occasions when men "get a dose of gas" at these places and suffer a night's headache are familiar to all who work about furnaces.

PRECAUTIONS IN GOING ON THE BUSTLE PIPE.

Men should not be allowed to go up on the bustle pipe to examine the water discharges, or valves, without notifying either the keeper, one of the tuyère gang, or the furnace blower; and if the job is likely, or proves to be, a long one, arrangements should be made for the men to relieve each other. It should be impressed on the man notified that he must remain on watch, or if it becomes necessary for him to leave his post, that he must arrange for some other man to replace him. It can not be considered essential that two men be required to go on the bustle pipe for each and every job. One man who is familiar with the work and acquainted with the possibility of there being excessive amounts of gas thereabouts is sufficient, provided always that some one has been notified and that the one so notified stays on watch. It should be impressed on every employee that if he should feel the slightest dizziness, weakness, or other symptoms of gas poisoning while working above he ought to come down immediately, not necessarily because he is in imminent danger of death, for he is not if a watcher is stationed below and a railed platform (Pl. I) is provided, but to prevent any possibility of his receiving a fall or burn through excessive dizziness, loss of muscular control, or unconsciousness. A watcher is essential. Nearly all of the deaths from gas at the bustle pipe have resulted from there being no one in particular who knew there was anyone on the bustle pipe.



VIEW AT BASE OF FURNACE, SHOWING BUSTLE-PIPE PLATFORM.

CHANGING BOSH PLATES.

When bosh plates are being changed the gas should always be "drafted back" through a stove before the plate is pulled; if the gas is especially bad, the furnace should be drafted back before the water connections are broken, for if the tuyère men or pipe fitters have worked in a gaseous atmosphere for some time, breaking permanent connections and providing temporary discharge and supply lines prior to casting or stopping to change the plate, they are likely to be in poor condition to undertake changing the plate. They may already be partly "gassed," that is, the hemoglobin of their blood may be partly saturated with carbon monoxide, and when it becomes necessary for them to again work fast in the same or a more gaseous atmosphere, illness or collapse may develop very suddenly. Therefore, unless enough men are available to work by shifts, or unless haste is imperative for some other reason than saving coal or loss of tonnage, the work of breaking connections and connecting the water discharge and supply can be done better and more safely with the blast off and the furnace drafted back. Such precautions are usually needless on the lower rows of plates; they are recommended only for the occasional plate on the top rows, a place which usually reeks with gas.

At the discretion of the foreman or blower, it is at many times advisable to light the gas under the mantle or at the plate box or arch when men are on the bustle-pipe platform or are changing plates. Lighting the gas will burn the noxious monoxide gas and is recommended in all cases where the job is a long one and the gas thick, unless the gas is escaping in such volume that the intensity of flame would present greater hazards than the asphyxiating possibilities of the unburned gas.

SAFEGUARDS.

As men may become gassed while working on the bustle pipe to such an extent that they lose control of their hands or legs, it is essential to safety that bustle pipes on which men must go several times daily be provided with platforms with a 6-inch toe board, intermediate rail, and handrail at least 3 feet 6 inches high. The platform preferably should not rest directly on the bustle pipe, but be supported on it by angle irons so that the floor plate will not become hot enough to burn a man if he should fall on it. Access to the bustle-pipe platform should preferably be by a stairway protected with handrails leading up from inside the cast house, and this stair should be the only means of access. To make sure that no one can go up on the bustle pipe without being noticed a swing gate that sounds an alarm on being opened should be placed near the top of the stairs or ladder. The device shown in figure 3 is in use

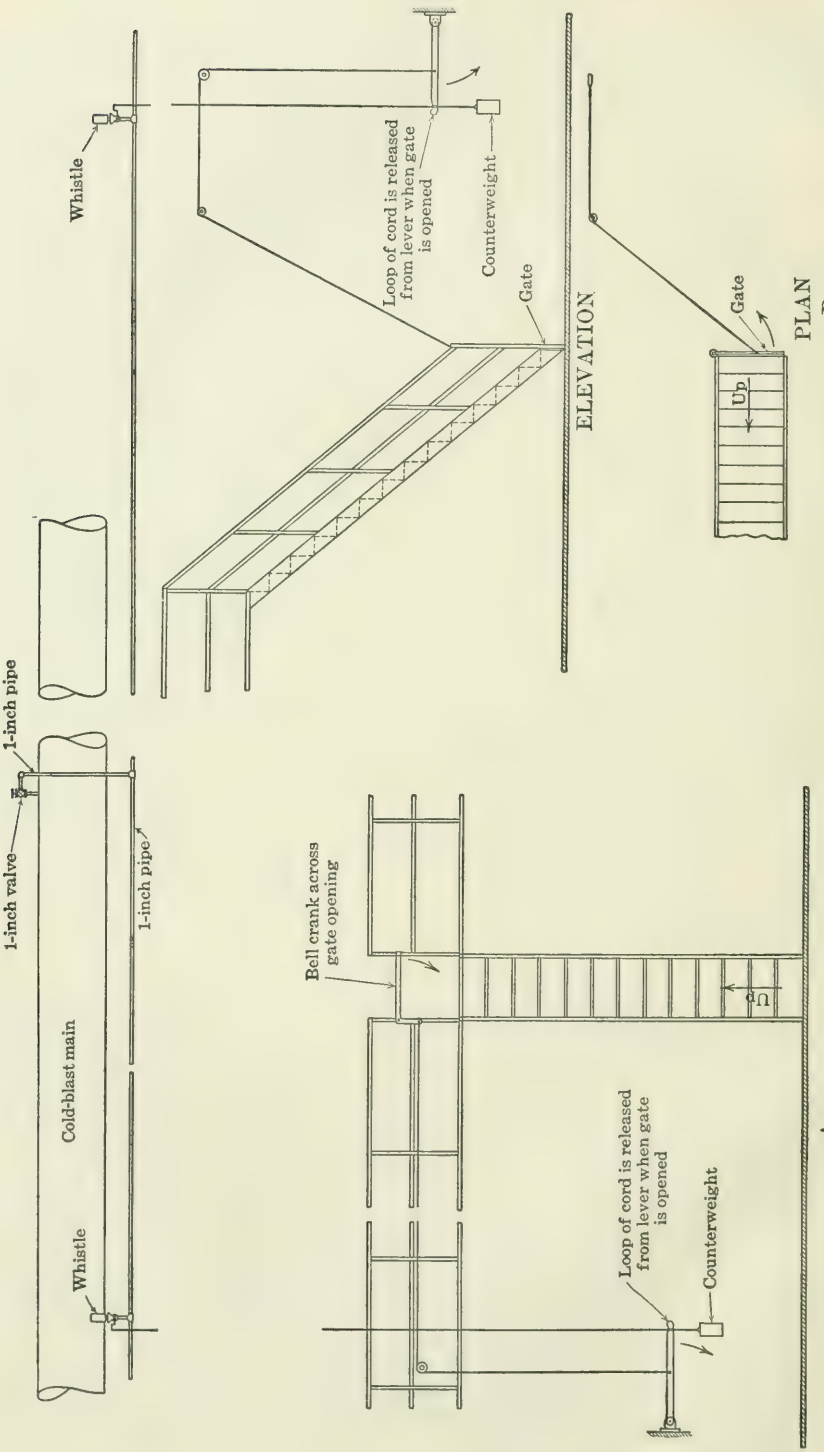


FIGURE 3.—Safety whistle for stairway to bustle pipe. *A*, Connections for gate at top of stairway; *B*, connections for gate at bottom of stairway.

by the Illinois Steel Co. To get up on the platform the water tender or other workman must open the gate, which, on being swung back, engages a catch that releases a steam or air whistle or electric gong, which continues to sound until the man comes down and closes the gate, thus calling the attention of everyone in the cast house to the fact that someone is working on the pipe. If the alarm sounds too long someone should investigate, but its prime purpose is to signal the keeper or hot-blast man to watch for the workman until he comes down. Such a device is recommended as practicable to all who wish to make this particular part of the furnace equipment safe.

A change in design or layout, such as has been instituted by a few plants, whereby the water supply circle or pipe is placed beneath the bustle pipe and the discharge water is taken care of in buckets or troughs attached to the furnace column, may be of advantage. Greater convenience, continuous inspection, and prompt attention to the hearth jacket, tuyère, and plate water supply and discharge are claimed; also the necessity of frequently going above and near proximity to gas accumulations about the mantle is eliminated.

Such an arrangement is not new by any means, as it is in use at plants built a generation ago, but certain plants of modern construction have reverted to this type. Discharging the water into buckets at the furnace column is not a common feature, but where in use causes little inconvenience and is somewhat preferable to the alternative of leading the discharge into the ditch about the hearth jacket. With an increasing tendency to eliminate ditches, the use of buckets is the only convenient means of disposing of the discharge, other than retaining the water trough above the bustle pipe. Unless this trough is high up above the bustle-pipe platform, workmen on the platform may, if overcome with gas, fall into the trough and be drowned. Such an accident has happened at one plant, and illustrates a place where two men should be required to go up, even on trivial jobs or errands of momentary duration. Such requirements can sometimes be enforced only by considerable diplomacy, reasoning, or discipline, and only an accident will impress on some the necessity of such precautions. For this reason it is not advisable always to require two men to go on the bustle pipe to examine discharges, adjust three-way cocks, or do other work, unless there is a definite reason, such as an abnormally gaseous condition at all times, impossibility of keeping men above in sight from the cast-house floor, or other local conditions. Insistence on rules of questionable necessity will bring into disrepute safety requirements in methods of work that involve hazards possibly not more apparent, but of more serious result, when persistently ignored.

FURNACE STACK.

REPAIRING COOLING PLATES.

Construction in which cooling plates are set in the lining at varying heights above the mantle, with the inlet and discharge pipes through the shell, requires occasional attention. These plates usually develop leaks as the lining wears back and the nose of the plate becomes exposed through cracks or abrasion of the brick to direct erosion by ascending gas currents and descending stock, together with a high temperature. Iron cooling plates are frequently attacked by acid water and develop leaks. When leaks develop or are suspected, it is often a most tedious and baffling task to determine which plate has failed, as the plates are always connected in horizontal or vertical series, and to detect a plate leaking water into the furnace requires breaking the connections from the discharge back to the feed pipe unless the leaky plate betrays itself by steaming about the inlet and discharge lines. Such work, except in rare instances, must be done in a gaseous atmosphere because of gas leaking from about the inlet and discharge pipes and rising from about the mantle. Where the shell is inclosed up to the top row of plates, gas accumulates in considerable quantities near the top rows and work for any length of time about the plates becomes difficult, because of the amount of gas, its reeking odor, and the necessity of working close to the jacket.

Bucket, trough, and spray-cooled thin-lined furnaces also require attention to the water supply; but, as a rule, the only gas encountered is that rising from the bosh, although leaks through the shell occasionally occur, by reason of failure or wear of the rivets. Tap-bolt construction obviates many gas leaks, not to mention the other structural advantages of using tap bolts.

USE OF WATCHERS.

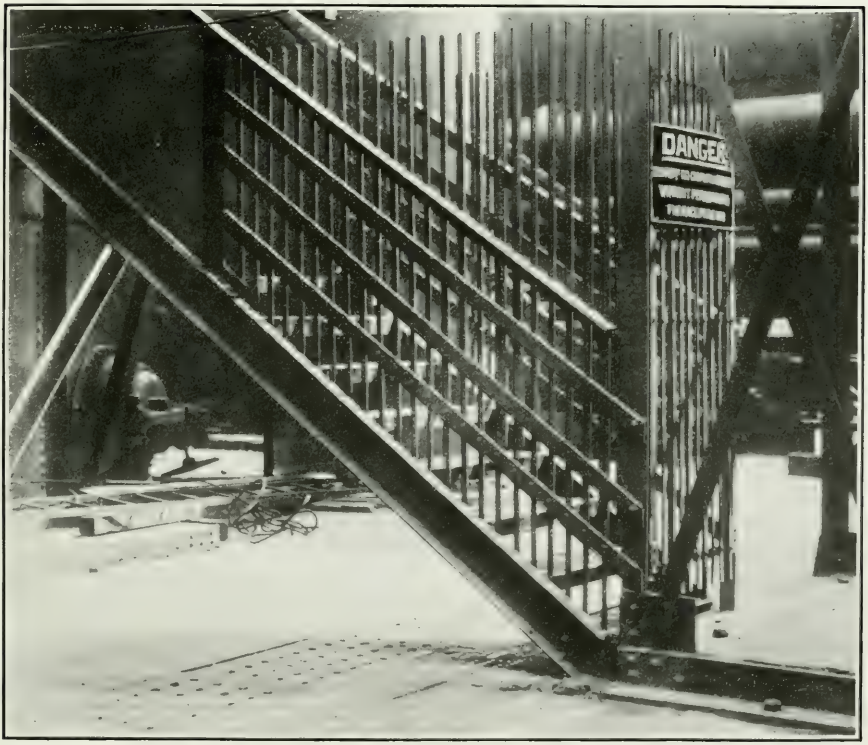
Inasmuch as men engaged in work upon high platforms about the jacket are likely to be out of sight of watchers on the cast-house floor level, particularly when they are at work on the side away from the tapping hole, two men should always be assigned to even the most trivial job, and a third man stationed as a watcher if it is necessary for the two men to work close to the furnace shell at the same time. The watcher, either of a two-man or of a six-man gang, should be stationed where there is no gas and in a position to keep the one or more workers in sight.

SAFEGUARDS.

GUARDED STAIRS AND LADDERS.

Permanent galleries with rails and toe boards, so situated as to permit easy access to the plates, should be installed, with permanent

A. STEPS TO FURNACE TOP. NOTE WIRE NETTING.



B. LOCKED GATE AT BOTTOM OF STAIR TO FURNACE TOP.

means of approach by stairs provided with hand rails. (See Pl. II.) It is often impracticable in old plants to construct stairways to the plate platforms, but whenever such is the case, a steel ladder with a safety-cage attachment should be provided as a means of approach. The number of serious accidents from falls and burns as a result of partial asphyxiation possibly exceeds the number of deaths from this cause, and any permanent device that will reduce the chance of injuries resulting from partial gassing should be installed. A cage about the ladder will lessen the probability of a man falling if he should, in attempting to come down while more or less seriously gassed, lose his hold on becoming dizzy or semiconscious. Such accidents have occurred, and to insure their not happening some such safety measure is necessary. Until such time as the plant can install guarded stairways or caged ladders to elevated platforms where they are not provided, men going up on such platforms to work in proximity to gas should be required to take up with them a life belt, or harness, and life line. In event of any member of the gang becoming gassed or showing symptoms of succumbing to gas, his companions should attach the life belt and line to him and send him down immediately, the men standing on the gallery or platform and keeping the line taut until he has reached the floor or can be assisted from the ladder landing.

USE OF GRID FLOORS FOR GALLERIES.

Opinion diverges as to the relative desirability of a grid or a plate floor for galleries about the furnace stack. On the whole, the grid floor is preferable. It may be made with strips or rods so spaced that tools and fittings can not fall through but the worker can be seen from beneath.

VENTILATION NEAR ROOF.

The junction of the roof with the furnace stack should be provided with a ventilating hood when the cooling plates are set so high in the shell that the water connections extend up close to the roof. The hood permits better ventilation and escape for gas than when the roof is snug against the jacket. When the plates are set above the roof, it is of course preferable that platforms with permanent means of access be provided. One instance is known of a man's becoming "gassed" while working on a plate connection above the roof and falling from the roof to the yard. Other cases of "gassing" have occurred which did not result fatally nor in loss of time, but necessitated delay and the difficult task of getting the man down to where resuscitation could be applied. Where galleries and convenient means of access are not provided, men should be provided with belts and life lines.

PACKING HOLES IN SHELL.

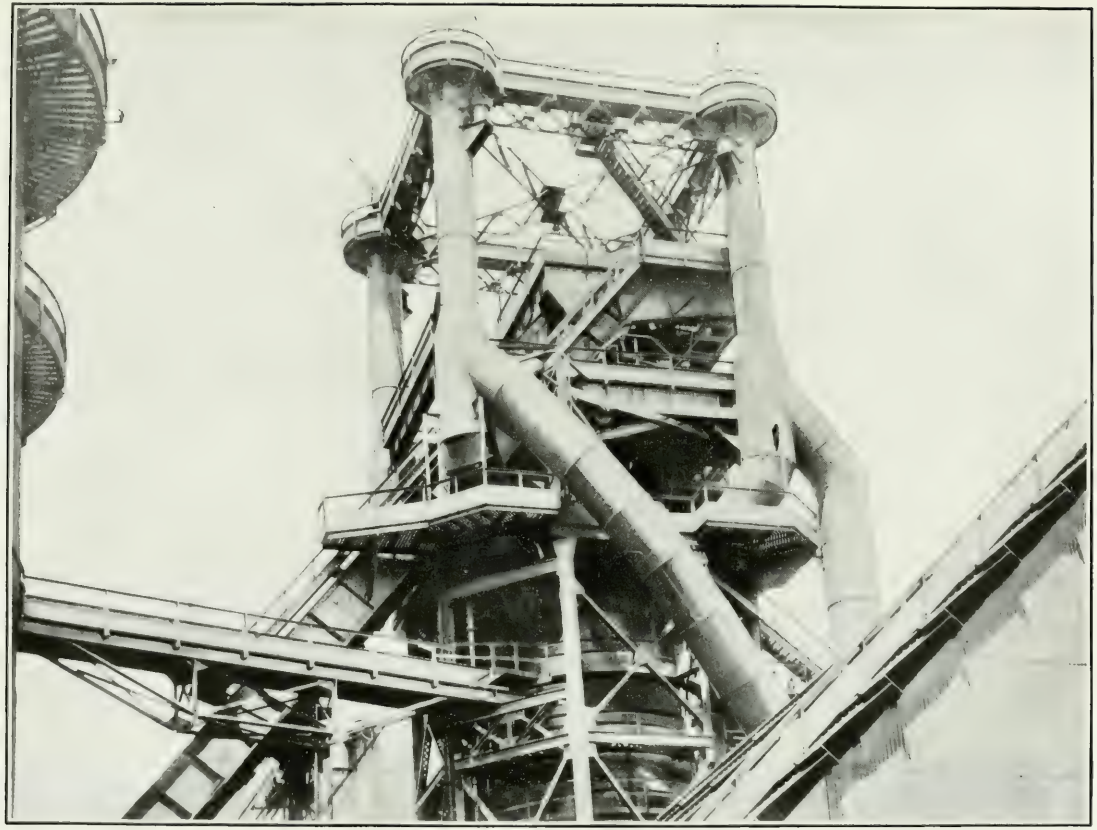
Very infrequently it happens that the shell burns through, shearing the rivets on the vertical, or occasionally on the horizontal, seams, when it becomes necessary to pack the opening until such time as the furnace can be blown out. Obviously this should be done as soon as possible, yet instances are not lacking of a furnace still being blown with an opening so large that it had to be repacked six or eight times a day. Although the packing is done with the blast off, it is trying work, as gas is continually blowing out, and men, because of their desire to finish the job and get away as soon as possible, work when they are experiencing symptoms of gassing, from the preliminary stage to loss of consciousness. In such work shifts of men should be provided under the direct supervision of the foreman, who should see that all necessary preparations and precautions are taken.

BLAST-FURNACE TOPS.

Blast-furnace tops (Pl. III) are never tight and they are notoriously dangerous. Mechanically filled furnaces, however, require men on top only at infrequent intervals—oilers once a day for 10 or 15 minutes to oil and inspect sheaves and brasses; riggers and millwrights once or twice a week to inspect the bells and hoppers; cleaners and repair gangs at occasional intervals to clean the top or repair and adjust sheave wheels, brasses, explosion doors, bleeder valves, hoppers, and bells.

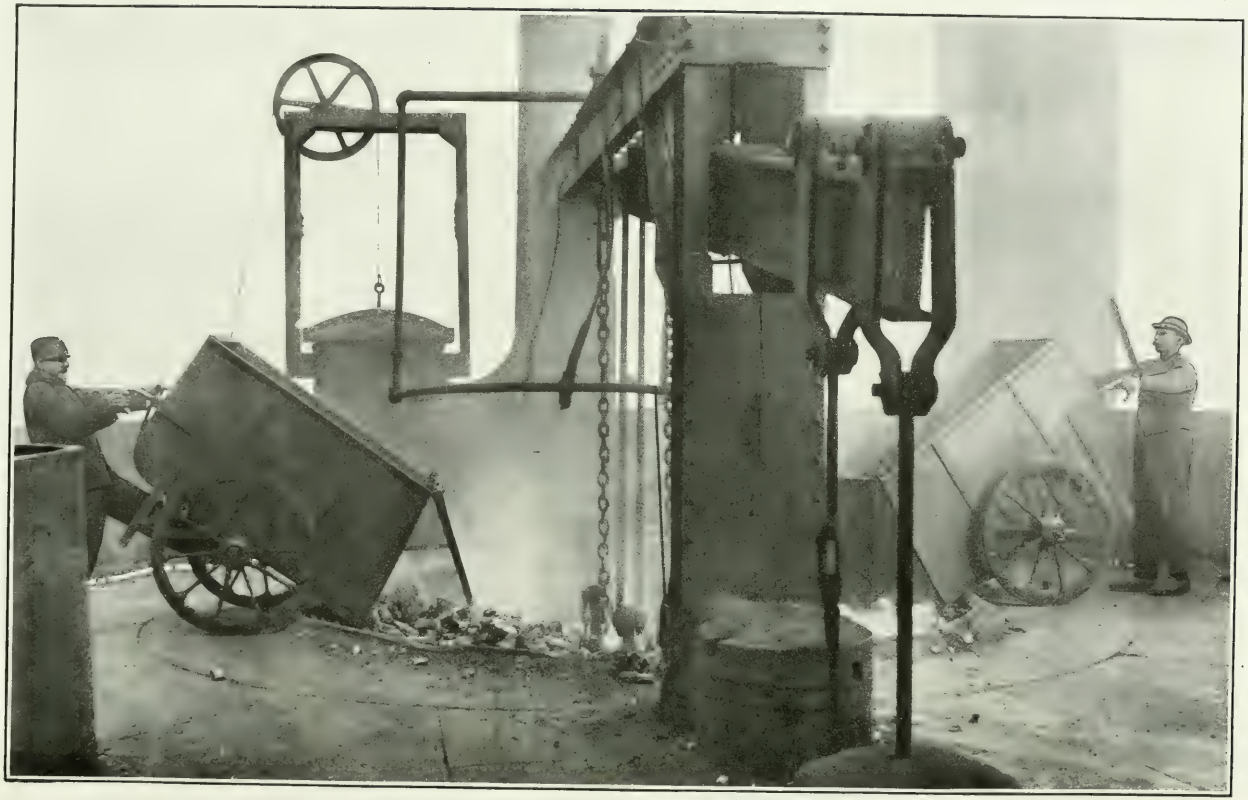
Gas is always escaping from about the try hole and may be and usually is escaping from one or all of the following: Gas seal doors, floor plates, explosion doors, and warped, imperfectly seated, or off-center bells and seats. The room available on the top platform is sometimes scant, access to sheave-wheel platforms is most frequently by ladders, the platforms themselves are largely over the receiving hoppers (see Pl. III), and in some cases the bell cylinders are also over the hoppers. Automatic distributor mechanism, telltales, and rodding devices require attention, and such work as inspecting bells and hoppers, removing lumps of ore or scrap, barring ore, replacing hoppers or wearing plates, and making occasional repairs and overhauling has to be done largely in gaseous air.

Asphyxia has happened in a variety of ways: To an electrician changing carbons on an arc light on the sheave-wheel platform; to a pipe fitter replacing a fitting on a bell cylinder; to a stock-house laborer "spelling off" a top filler; to a laborer engaged in cleaning the top platform; to an oiler who fell from the sheave-wheel platform to the changing platform in attempting to get down when partially overcome with gas; to a rigger repairing the telltale on the top rigging; to his helper who tried to rescue him; to a top filler (Pl.



FURNACE TOP.

Note three means of ascent and descent—by walk at left from stove, by stair from below at left, and by stair at right from cast house. Note also railings on stairs and walks, the high toe boards, and the perforated construction, by which workmen can be seen from below.



TOP FILLERS DUMPING ORE INTO OLD STYLE OF FURNACE.

Note dimness caused by gas rising from hopper.

IV) who was overcome with gas from a leaky explosion door and fell into the hopper; to a millwright who fell down the steps from the furnace top while partially overcome; to another millwright who was found on top overcome with gas; to seven men who attempted repairs to the small bell rod inside a receiving hopper; and in various other instances noted herein.

NEED OF WATCHER.

Workmen should always be required to notify the furnace foreman or blower before going on top (see Pl. II) even in pursuance of their routine duties of oiling or inspection, and not less than two men should go on top even for minor jobs. One man should act as a watcher, remaining away from the furnace top, out of range and danger of gas; for example, on the No. 2 stove in such a position that he can watch the man or men at work. If one or more men show signs of distress from gas or call for help, the watcher will be able to give an alarm to the stock house, cast house, or bell operator, summon assistance, and then, if possible, help the endangered man from the gaseous atmosphere or keep him from falling.

PRECAUTIONS IN OILING.

Oilers should be instructed not to go on oiling platforms above the bells without first notifying the bell operator not to open the bells until he receives a signal from them to resume charging. If it is possible to do so, the switches or levers that operate the bells should be locked or blocked in closed position before the oilers go about the bells, to prevent the accidental lowering of either bell through misunderstanding. Such a provision is especially recommended in case the bells or seats are warped or leaky, for it is frequently the case that although the small bell remains closed, dumping an ore charge off the large bell will allow excessive quantities of gas to escape through both bells on account of imperfect juncture between the bell and seat once the sealing effect of an ore charge is removed; dumping the small bell may result in the same condition.

MEN SHOULD NOT BE ALLOWED ON TOP WHEN FURNACE IS LOW OR HANGING.

Men should not be allowed to go on top while the stock line is low unless absolutely necessary because of delay or repairs, as the gas pressure will be stronger and there may be a greater tendency toward a sudden "roll" or "slip" that, besides the danger of burning the men, may cause larger amounts of gas to accumulate about the top rigging from explosion doors opening or leaking more freely.

Men should never be allowed on top, under any circumstances, when the furnace is known to be hanging—the dangers of asphyxiation and burns are obvious. Inasmuch as it is not possible always to know at what time a furnace is going to slip, it is advisable, when a furnace is working stiffly or irregularly, to have the furnace blower check it before the men go on top and hold it until the signal is given that the men are down.

INSPECTING HOPPER AND BELLS.

Before any one inspects the receiving hopper and bells in skip-filled furnaces the operator should be notified to stop charging, except on signal from the foreman in charge on top. Such work should never be undertaken without obtaining permission from the furnace blower, regardless of its being a regular weekly or daily routine job, for aside from the hazard of gas, which may be adequately provided against under normal conditions, circumstances may require that the furnace be temporarily shut down for other reasons. If only a cursory inspection is contemplated to ascertain whether the bell and hopper is cleaning properly and not accumulating at some point a "scab" of ore large enough to prevent even distribution of stock, it is rarely necessary to take the furnace off. In case more thorough inspection is undertaken, such as measurements to determine whether the bell is off center, inspection of the stock line, or repairs to the hoppers, bell rod, or bells, the furnace should be shut down and the tuyères plugged. If the furnace is connected to other furnaces in operation, the gas valve should be closed, the bleeders and explosion doors on top of the furnace opened, the dust bell on the dust catcher opened, the gas lit on top of the stock, and a man delegated to see that it stays lit. A similar procedure should be followed in case repairs must be made to explosion doors or bleeder valves.

CLEANING THE TOP.

Whenever it becomes necessary for a foreman to take the labor gang up to clean off the furnace top, precautions similar to those described for routine oiling and exterior inspection should be followed. It is usually best not to have a fixed day for this job, but to select one when there is a good breeze. Enough workmen should be used so that part of the crew can be placed at some point not gaseous to watch those at work and spell them off. The foreman in charge should stay continuously on top during the work.

SAFEGUARDS.

PULLING OUT BUGGIES.

At one hand-filled furnace where, as at most furnaces of this type, the top fillers occasionally allow a buggy to drop into the hopper,

a hook with block and tackle is provided so that the buggy can be pulled out without the filler having to work in the gas. The end of the rope is attached to the hoist, which is lowered under the control of one of the top fillers until the buggy swings clear of the top of the hopper, when it is swung over onto the charging platform.

At another furnace a rail which is attached to the two structural columns at each side of the hopper, encircles the hopper at such a height that it will catch the buggy and prevent its overturning into the hopper. Top fillers at work dumping buggies are shown in Plate IV.

PREVENTION OF GAS LEAKAGE ABOUT HOPPER AND BELL.

AT OLD FURNACE TOPS.

The practice of suspending a lighted coke or coal brazier at the side of the hopper to keep any considerable leakage of gas continually lighted is preferable to the practice of lighting the gas with burning waste or coke at each lowering of the bell. The first method obviates the possibility that gas escaping from about the bell and hopper-extension junction may accumulate by neglect to keep it lighted.

At certain old-type tops, when the charging-platform plates are not riveted to brackets, and the hopper rests on the lining and is not bolted down to a top or "bull" ring secured to brackets, I-beams, or the shell, there is apt to be excessive leakage of gas if the furnace has been on blast long. These leaks are almost impossible to stop while the furnace is in operation. The closing of the bell is constantly jarring the hopper and loosening it, while the packing beneath the floor plates becomes cracked and permits an increasing emission of gas as the dusty gas erodes the fissures. Such leaks can as a rule be overcome only by stopping and resetting the hopper or repacking the floor plates. Hopper trouble is now practically a problem of the past, as relatively few furnaces have not done away with the old hopper arrangement by having the hopper bolted onto I-beams or brackets on which it is rigidly held. The packing beneath the floor plates and the top of the lining is of late years done efficiently by putting 9 to 24 inches of concrete, loam, and grout on top of the lining. Examples of methods of packing are: (*a*) 3 inches of loam tightly rammed; 3 inches of concrete, 3 inches of grout, floor-plate; (*b*) 12 inches of concrete, 4 inches of grout, 6 inches of loam, floor plates; (*c*) 15 inches of concrete, about 1 to 2 inches of grout, 6 inches of asbestos wool packed with water glass; (*d*) 6 inches of loam, 6 inches of concrete, 2 inches of grout, 6 inches of loam. The tops of all hand-filled furnaces visited by the writer during 1915 have been, with two exceptions, in first-class condition as regards leakage about the floor plates and hopper. This statement does not include

leakage between the hopper and bell; here the inevitable warping or wear has at a few plants resulted in excessive gas about the top. Seemingly such leakage has not resulted in serious injury to top fillers, as they are "spelled off" frequently enough to prevent accidents resulting in death or lost time, but the general effect on their health can not be beneficial. Such conditions are usually of temporary duration unless the furnace is nearing the end of the blast, when the operator is not inclined, sometimes for valid reasons, to stop and change bells or hopper lips for the few days or weeks before it will apparently be necessary to blow out. The actual accident hazard in such conditions does not lie so much in the usual routine work of top filling as in the possibility of a combination of unfavorable atmospheric and furnace conditions, such that the top fillers and the relief men have to work in air so gaseous that they may be seriously affected. Such cases are extremely unusual, but fatal results are on record.

At blowing in, a few very serious cases of asphyxiation have happened to top fillers, foremen, and superintendents, and similar cases have occurred in blowing out. In such instances, the bell being left open, there have been accumulations of gas so unusually rich and noxious that traces of it overcome a man very suddenly. Being accustomed to working in gas of normal carbon monoxide content for a brief time, the men were overcome in a fraction of the time that they considered insufficient to cause serious symptoms of asphyxia. At such times, as it is essential to have men on top, there can only be urged extreme caution, the use of thoroughly experienced men, and the presence of a foreman.

To take care of the contingency of excessive gas accumulation, in the most recently constructed hand-filled furnaces (those built within the past 10 years, 1905–1915) the hoists are placed back a considerable distance from the furnace, the length from center line to center line being upward of 40 feet. A tightly constructed house with entrance away from the furnace is also provided at the rear or side of the hoist. Some old hand-filled furnaces do not have such refuge houses, and the men at best can not get very far away from the furnace top when resting between spells.

TRY HOLES.

The try hole frequently becomes a source of excessive gas leakage owing to erosion by coke dust in the gas. The most satisfactory try hole arrangement appears to be a sleeve of extra heavy steel pipe of diameter sufficient to clear the try rod. The pipe is screwed into a flange machined on the face at an angle sufficient to give the try rod and sleeve the necessary slant to bring the try rod over the stock. As the sleeve projects above the flange of the rodding hole, the hole

in use can be provided with a hinged cover similar to bar-hole stoppers in gas producers, and the three holes not in use can be capped. When men are working on top, the try rod can be withdrawn and the cover closed temporarily. The three try-rod holes not in daily use are large enough to permit 1¼-inch or 1½-inch spray pipe to be inserted when blowing out.

The try holes on hand-filled furnaces have been, with but one exception, covered or stopped with a plate, bolt, or plug when not in use for gaging the stock line. They are occasionally found inside the hopper, being a bolt hole through the top of the hopper extension and the hopper lip. On hand-filled furnaces, the gas from about the try hole is usually of little consequence. Skip-filled furnaces with higher gas pressures have been noted where the gas was decidedly thick about the top from escaping from the try hole alone. It is a good idea to keep a supply of rope asbestos on top and pack the try hole whenever it is necessary to work there.

LIFE LINES.

Life lines and belts should be provided and kept in some secure and readily accessible place on top of the stoves, for use in case it becomes necessary to rescue a workman from the top rigging, and also for use by anyone who has to venture for repairs into an atmosphere that may become gaseous, notably on the top rigging, or inside the gas seal or hopper.

EMERGENCY STRETCHER.

An appliance that has been introduced at the Lucy furnaces, and which should be a feature of safety equipment at all skip-filled furnaces, accessible only up the skip incline, is a stretcher (Pls. V and VI) suitably made for securing in position any man overcome by gas while on top and for lowering him to the ground. It is to be recommended in consideration of the fact that men occasionally become delirious when gassed, and resist the men attempting to get them down off the top, or are so helpless as to be brought down the skip incline only with the greatest difficulty.

ALARM GONG.

To enable watchers, or an inadequate number of men, on top to summon assistance in case of need, it is essential that there be provided means for attracting some one's attention, rather than having the men under the necessity of shouting down to the yard or trestle at random. A gong is preferable, located at the skip operator's post and operated from the stove platform, together with a speaking tube or telephone for communication between these points. The bell or skip operator should remain on post continuously so long as

there are men on top. It is even better to have an additional gong in the cast house, because some one is always on duty there.

PLATFORMS AND RAILINGS.

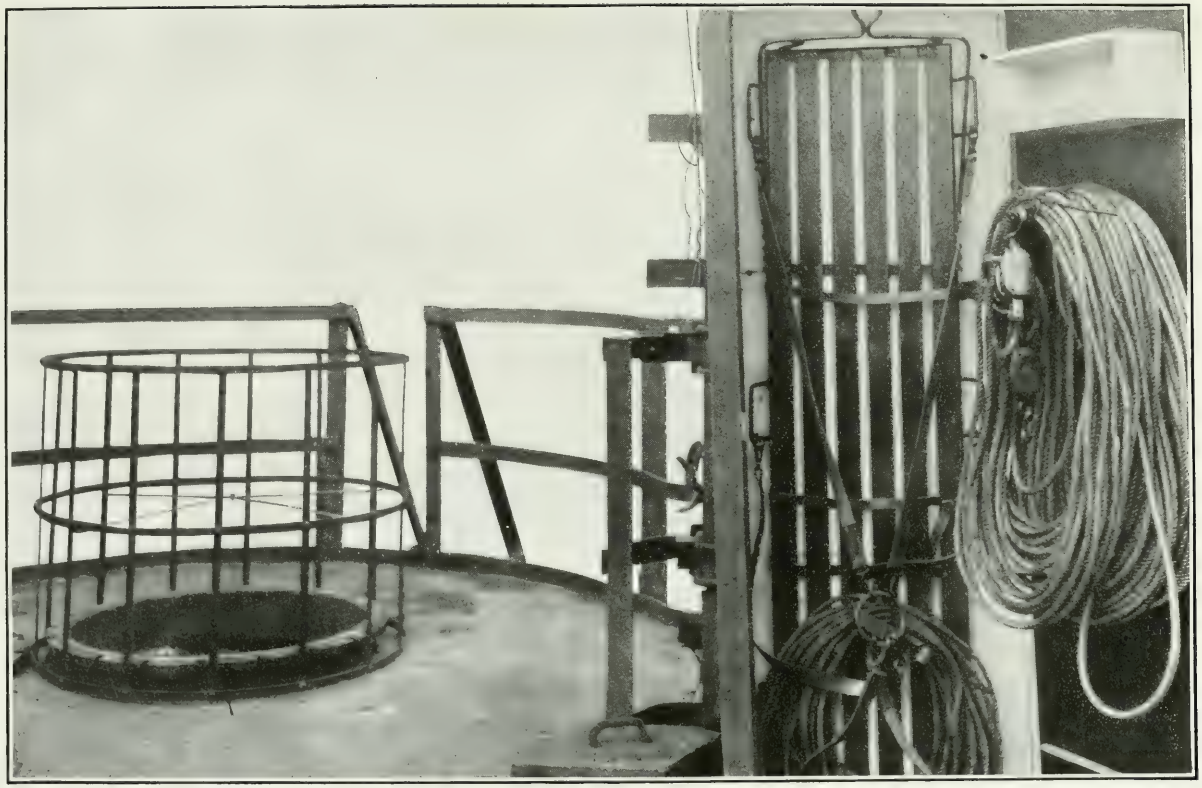
When it is necessary for men to go up regularly and bar frozen ore off the hopper during cold weather a railed platform should be provided for their use. In case lumps of frozen ore of larger size than will go through the throat or little bell are detached from the hopper, the furnace should be taken off, and a life line and belt attached to the workman assigned the task of breaking up the lump or removing it. For instance, a man, though working under the direction of a foreman, in attempting to break up a lump lodged between the small bell and bell seat slipped through onto the big bell, and in attempting to rescue him the foreman went in through the gas-seal door with no life line attached and lost his life by being overcome with gas.

Fatalities and severe injuries have occurred through men becoming partly overcome by gas, and in this condition slipping between the toe boards and intermediate railings of standard railings, though it is difficult to imagine in what manner. Following such accidents, certain plants have sheathed the railings of platforms exposed to gas and steps leading to them with wire netting (see Pl. II), or if ladders are used, have provided cages about them, as has been recommended in a previous page. This is to be preferred to a plate railing continuous from platform to hand rail, as it permits an open view from the ground or other station point for watchers.

Also many serious injuries have resulted from men stumbling or tripping while descending stairways in a dizzy or weakened condition from gas. The possibility of a tumble from the point of collapse to the yard or foundation landing is generally taken care of by providing intermediate landings, though many plants are to be found where the approach to the furnace top is by a straight stairway up the skip incline. Besides such means of approach, there should be provided, and generally are, steps from the stove-top platform to the ground, where provision can be made to provide landings for every 30-odd feet of stairway.

LOCKED GATES AT FOOT OF STAIRS TO TOP.

Locked gates (see Pl. II) at the foot of all stairs to the top of the furnace are not provided at any plant visited. In the opinion of the writer, a gate for each stair is not generally necessary, but all stairways to the top not in the direct range of vision of some responsible employee regularly stationed nearby might well be provided with a gate and the gate locked, and the key kept in the furnace office. Steps up the skip incline, if within sight of the skip operator,



EMERGENCY STRETCHER AND TACKLES ON TOP OF BLAST-FURNACE STOVE. GUARD FOR MANHOLE.

FIRST-AID CREW LOWERING ASPHYXIATED MAN FROM FURNACE TOP IN AN EMERGENCY STRETCHER.

may be left accessible, but should be provided with an alarm gate, the opening of which will operate a bell or light at the skip operator's station, so that he may always be advised and determine how many men are going on top. The necessity for some such provision is illustrated by a recent fatality. At the plant where it happened, there was a standing rule that never less than two men should go on top. The foreman ordered two men to go up and make some minor repairs. One of them was delayed, and the other went to the top alone. When the second workman arrived on top, the first man was found overcome by gas, and could not be resuscitated. The foreman had assumed that his directions would be followed; both men knew the hazard, and although it seems unlikely that any sane man would deliberately ignore well understood safety rules, men assigned routine or occasional work that takes them on top, too frequently display fear of being thought to be loafing, contempt of danger, or disregard of standing orders although given directly and repeatedly. Although ignoring safety rules concerning methods of work may not result in accident, a considerable proportion of the accidents from asphyxiation are so caused. The difficulty lies in the fact that experience has shown both foremen and workmen that jobs of the above character, for instance, can be undertaken and finished without injury 364 days of the year. When such accidents do happen, they are usually serious. It is evident that work of this nature requires precautions that perhaps may seem useless or unwarranted, such as the explicit following of rules and directions for minor details of work, and warrants providing means of preventing men going on top, such as locked gates, at every flight of steps leading to the top unless the bottom landing is in full view of the skip operator. It is not implied that employees of the rank of skipman should or ought to have the authority to prevent workmen from going on top, but the skipman can be trained to notify the blower, stock-house foreman, or other responsible party with whom he can first get in touch.

ILLUMINATION OF FURNACE TOPS.

The illumination of furnace tops is occasionally deficient, considering that many types are subject to derangement and delay on account of parts getting out of adjustment. Infrequently the stock-house crew and sailor gang must go up into the top rigging at night when the only light available is a single arc, or cluster of incandescent lights, arranged primarily to illuminate the top travel of the skip with little attention directed toward adequate illumination of sheaves, bell cylinders, valves, or operating mechanism. Work of this nature, though infrequently required, is hazardous because of the gas and the fact that work on elevated structural construction must at times be performed away from platforms provided for routine

duties. A number of plants keep an emergency set of incandescent clusters with extension cord and plug, for use at such times, at the office of the stock-house foreman or on top. At least one plant is considering the advisability of placing a low-intensity searchlight on the stove next the furnace to illuminate the top when men must work in the rigging at night to make emergency repairs or adjustments.

REPAIRING FURNACE LININGS AT THE STOCK LINE.

Work at the top is extra hazardous when failure of the lining at the stock line makes it necessary to bank the furnace for some hours or days in order to renew the lining. Two fatalities have been noted from work in this connection. This work is infrequently done, and many superintendents prefer to blow out the furnace rather than to attempt it, believing that any repairs of this nature will at best be only temporary, that the work is too hazardous, or that too much importance is attributed to the detrimental effect of the wear of the lining at this point, provided it does not extend back so far that the shell gets hot.

Considerable annoyance and difficulty is experienced from gas during such work, and in some instances practically all of the men available become more or less incapacitated. One instance may be mentioned in which the furnace before stopping was blown down from a 14-foot to a 35-foot stock line. After casting, the furnace was filled to a 20-foot stock line with regular charges, the last charge being fine ore. The top was then opened and the gas lit on top of the stock. After the bells and hopper were removed and a scaffold slung on which to tear out the brickwork, the heat from the burning gas made it impossible to keep at work. The gas was put out with a hose, and the men again went down upon the scaffold. This time they quickly became affected by gas, it being necessary to remove some of them with ropes. The work was interrupted to hoist up more ore, dump it, and spread it on top of the stock, and clay up the bosh. In the best of circumstances it was found feasible to work only in short spells with the gas lighted and when the heat became overbearing, with the gas extinguished, when one after another of the crew became ill and occasionally a man became unconscious.

The practice followed and noted at three plants is briefly as follows:

All open cracks in the brickwork of the bosh are luted up, the tuyères are tightly plugged with clay, and every precaution is taken to insure that the minimum quantity of air enters at the bottom and consequently that the least amount of gas is given off at the top. The furnace was blown down to 40 feet and was filled with the blast off. The last charge consisted of a double round of coke followed by a

double round of Mesaba iron ore. The gas was lighted on top of the stock before the gas seals, hoppers, and bells were removed. When these had been removed, the gas was extinguished, a ladder lowered, and two men with life lines attached went down and quickly dug a hole in the center where the ore was thinnest, uncovering the coke to a depth of about 1 foot. Another shift went down and placed a 6-inch pipe in this hole and shoveled the ore back about it. A third shift leveled the ore off to some extent, wet it down, tamped it solid, and covered it with loam. The two coke blanks, being comparatively open, permitted a lateral displacement of gas to the center, where it escaped up the pipe. The brickwork was then quickly repaired with no annoyance from gas.

At the second plant precautions similar to those at the first plant were taken in stopping air leaks at the bottom. After the receiving hopper, little bell, and gas seal had been removed, chain blocks were attached to lugs on the main bell, the bell detached from the stem and lowered away from the hopper extension. A length of 4-inch pipe with an 18-inch nipple screwed into a 90-degree elbow at the bottom was then lowered until it rested on the stock, which was in this case a coke blank. The bell was then lowered until it rested on the stock and ore shoveled in until it sealed off the space between the bell and the lining. The gas was led away effectively through the 4-inch pipe projecting above the lip of the bell. Some difficulty was found in raising the bell because the ore, of which too much had been shoveled in, tended to wedge it.

The third method was used on a hand-filled furnace in eastern Pennsylvania and is in effect the method described by Firmstone.[a] The furnace was blown down to about 35 feet, a large coke blank filled, and the hopper extension and bell removed. A false or "dummy" bell, or cone made of $\frac{3}{8}$-inch sheet with a 9-inch sleeve and pipe extension on top was then lowered on top of the coke blank and the furnace filled with regular charges to the point where the regular work started. The pipe effectually removed the gas and when operations were resumed as much of the pipe as would come away was removed, the rest of the apparatus being left in the furnace, the furnace filled, and started up again. Such a method is more applicable to the few remaining hand-filled furnaces than to skip-filled furnaces.

One instance is known where the furnace, after being off blast for about 14 hours while repairs to the stock line were being made, slipped violently. By singular good fortune, no one was injured. Such an incident is of course a remote possibility and is not illustrative of the usual hazard of such work. As previously stated, most furnace men,

[a] Firmstone, Frank, Repairs to blast-furnace stock lines: Trans. Am. Inst. Min. Eng., vol. 4, 1875, p. 29.

having in mind the difficult character of such work, the gas hazard, and the fact that causes other than wearing of the stock line may be responsible for the unsatisfactory behavior of the furnace, do not desire to undertake stock-line repairs unless the furnace is blown out. On the whole, this is probably the best policy, but under the push of large orders or heavy mill operations, or with good furnace practice and a hot shell or mechanical failure of wearing plates requiring attention, stock-line repairs will probably continue to be undertaken, though less and less frequently.

USE OF WEARING PLATES.

The stock line is protected in most furnaces nowadays with cast-iron or steel (cast or rolled) wearing plates, and although early attempts at mechanical protection were frequently failures, because of the character of the metal and the method of placing the plates, recent blasts have proved conclusively that wearing plates are practicable, that they outlast the blast lining, that they do not necessarily warp, and distort the distribution, nor work loose and carry out segments of the lining, and that they do not expand enough to shear the rivets on the shell. Many plants that formerly had to interrupt the blast campaign for stock-line repairs have not found this necessary with any linings during periods of the past two to seven years.

HOT-BLAST STOVES.

CAUSES AND EXAMPLES OF ASPHYXIATION.

At work in or about hot-blast stoves, the hazard of asphyxiation is from gas leaking from the stove burner, adjacent burners, or mains, from gas working back in the stove while it is being drafted back past the stove, or from the gas being turned into or drafted back through a stove by error or ignorance. The hazard from such sources seems so slight that mention of it might be considered unwarranted but for the fact that improbable accidents have happened from most of these causes.

A rigger sitting in a boatswain's chair and tearing down the skin wall in a well was overcome with gas, which was being drawn in from a leaky burner through an open burner door, and fell to the bottom of the well. A stove cleaner entered the dome of a stove on which the hot-well doors had been opened to cool the stove off, before the burner door had been closed and gas from the burner, which was leaking badly, killed him. In drafting back through an additional stove, a stove tender in a hurry lifted the hot-blast valve on a stove being cleaned. In another instance men working in a stove next the furnace were severely gassed by leakage through the hot-blast valve and seat when the furnace was drafted back through a stove farther

from the furnace. A stove tender was asphyxiated by gas escaping from a dust-box door between the down leg and burner valve.

PRECAUTIONS IN CLEANING AND REPAIRING STOVES.

LOCKING VALVES.

Before the stove cleaners are allowed to enter a stove to clean it, it is becoming accepted practice to shut and lock the gas burner, or burner valve. (Pl. VII, *A*.) The stove cleaner foreman, blower, or other responsible employee is given this duty. The hot-blast valve is blocked or strapped on its seat by means of the valve stem, this being found preferable to locking the cable winch. When the counterweight is within reach it is blocked up or enough slack in the counterweight cable is otherwise obtained so that the entire weight of the valve is seating it against the valve seat. At a few plants the cable is detached from the hot-blast valve stem. For all practicable purposes, it is sufficient to slack off on the cable and lock the winch. A method of applying a safety lock to the operating wheel of a hot-blast valve is shown in Plate VII, *B*. Though not in any way related to the possibility of gassing, it is good policy to provide a lock for the cold-blast valve or operating cables while fitting up burners and hot-blast valves.

PROVIDING AGAINST GAS LEAKS FROM BURNERS.

All types of stove burners must of necessity be withdrawn from the burner door, either by racking back the burner or by sliding back an extension sleeve when the burner door is closed. If gas is leaking at the burner nose the logical thing to do is to close the burner door, and this is the usual custom at practically all plants. A burner or burner valve is not a closely machined piece of apparatus, and when used with uncleaned gas the abrasive action of the dust sooner or later causes leaky seats and not infrequently a perceptible leakage at the nose of the burner. With clean gas possibly even more care is required, for gas leaking in dangerous quantities may be drafting into the burner door and be undetected by the eye. So whether gas leaks are in evidence or not, it is a good standing rule to close and fasten the door. There should always be ample draft through the air inlet or cleaning door, blow-off or relief valve, and the chamber door of the hot-blast valve. When it becomes necessary to leave the burner door open it is usually possible to turn a gooseneck burner on its seat or flange, at an angle of 90° from the door, also a burner with interior seating valve that leaks perceptibly can usually be handled in this way. At some plants the burners are removed and a blank clamped into the seat; other plants insert blank flanges. At one plant burners of both types, gooseneck burners or

dust boxes and burners with interior seating valves in the down leg or main, have been experimentally equipped with a water seal by attaching inlet and outlet water lines to the down leg. This is possibly most feasible with low gas pressure; it is also a somewhat debatable step. With badly leaking equipment of certain types, however, the idea may be applicable to good advantage.

If gas is escaping about the burner seat, or from adjacent burners because of leaking gas, gas puffing from the burner door of dirty stoves, too much gas, poorly designed burners, or from other sources in proximity to the bottom doors of stoves being cleaned, precautions are necessary. Although it is rare that conditions are troublesome from the causes mentioned, in some instances stove-cleaning gangs have suffered illness, headache, and loss of working efficiency from them, and in one case a stock-house crew working alongside the stoves was made ill whenever a breeze was blowing the gas in under the trestle and bins.

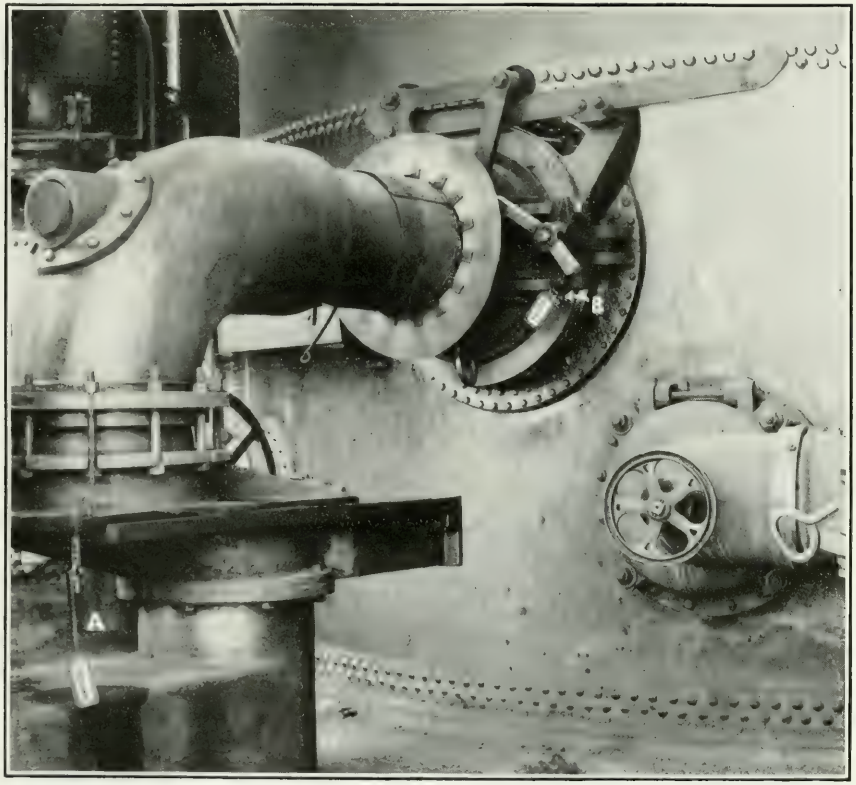
Brief mention was made of the asphyxiation of a stove tender by gas from a leaky dust box. This accident occurred at night when the air of the outside atmosphere was heavy and still, and in all probability asphyxiation was caused by accumulative saturation of the blood with carbon monoxide over a period of hours, until a condition was reached where staying longer than usual in the gas caused unconsciousness.

WHEN TO KEEP OUT OF A STOVE.

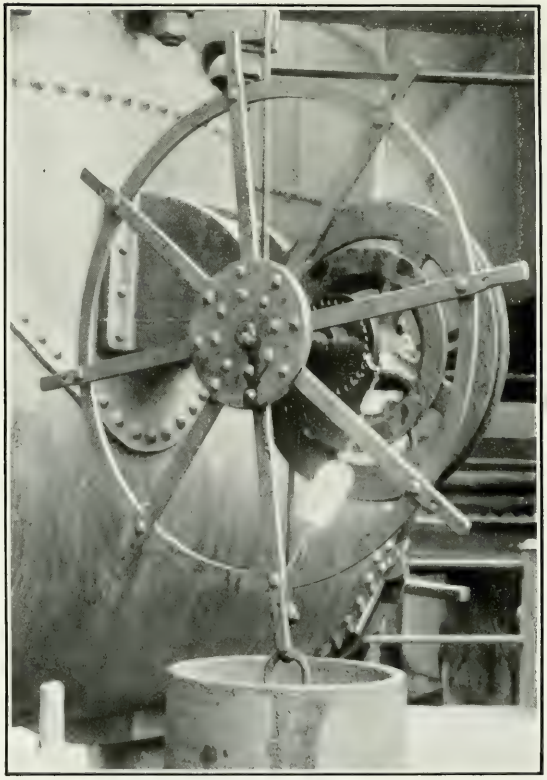
After leaks into the stove and negligent opening of valves have been provided against, the following precaution should be borne in mind: To come out of the stove when the furnace is being drafted back past the stove, if the furnace is being given more than two checks to make it slip or is to be taken off for a shutdown. The seal of the hot-blast valve against the seat is at times poor, and as previously shown it is possible for gas to leak back into the stove. The observance of this precaution is not universal, by any means, and is largely determined by local conditions, upkeep of equipment, and the judgment of the furnace foreman. Not a few furnace men believe that, with their plant conditions and practice, it is preferable to be inside the stove rather than outside, when the furnace is slipping heavily. If any one feels the slightest symptoms of gas poisoning he should get out of the stove at once, while he is able to do so.

SUPERVISION OF CREW.

It is rarely possible to have the stove-cleaning men under the constant supervision of a foreman. To meet this difficulty, it has been found satisfactory to select from the crew the man who best understands the work and the requirements for proceeding with it safely,



A. METHOD OF LOCKING VALVES ON HOT-BLAST STOVE. A, FOREMAN'S TAG AND LOCK ATTACHED TO PIN THROUGH BASE OF BURNER VALVE; B, TAG LOCKED TO CLAMP BAR ON GAS DOOR.



B. SAFETY LOCK ATTACHED TO OPERATING WHEEL OF HOT-BLAST VALVE; THIS LOCKS WHEEL IN POSITION.

and delegate to him the responsibility of the foreman for the careful carrying out of the work. To him should be explained the dangers from gas.

METHODS OF VENTILATION.

There is rarely any difficulty at blast-furnace plants from inadequate ventilation. The stoves are sometimes very hot, but where there is one main draft stack usually ample air can be drawn up through and down the stove by means of one open chimney valve. Two-pass stoves with individual stacks will not draw satisfactorily at times, and at one plant a steam-jet exhauster is placed in the stack of the stove off for cleaning, for as long a period as is necessary to keep a good current of air going through. There is little difficulty with three-pass stoves, the current of air usually being ample, although sometimes an exhaust fan is attached to a cleaning door at the bottom of the second and third pass. On two-pass stoves there is occasionally some anxiety about losing too much draft and heat efficiency in the remaining stove equipment if the central stack draft is utilized to ventilate the stove off for cleaning. If in such a case only the draft from the bottom doors up through the stove to the dome door is utilized, a very unsatisfactory ventilation results. One plant, to conserve the stack draft, shuts the stove off the draft flue, but employs an exhaust fan at a bottom cleaning door under the checker arches. With adequate ventilation, locked valves, and attention to leaky gas equipment there will be no trouble from asphyxia inside of stoves.

FOREMAN SHOULD SEE THAT MEN ARE OUT BEFORE TURNING ON GAS.

Before closing dome and bottom cleaning doors and turning the gas into the stove the foreman in charge should personally satisfy himself that all men are out of the top and from beneath the checker arches. As an incident illustrating the advisability of this precaution, a foreman inspecting the checker keys before having the bottom doors closed found a workman resting or sleeping underneath the arches. Such incidents occur only rarely and at few plants, and no one but an ignorant, irresponsible laborer, such as is necessary to hire at times, would select such a place to rest in. For such men the company should take every reasonable precaution to insure their safety.

GAS-FIRED BOILERS.

The danger of asphyxiation about gas-fired boilers is from working inside the combustion chamber while the burner is leaking or gas is being drawn into the chamber from leaky equipment in the vicinity; resting near burners; and working on steam equipment on top of the boilers or on steam lines and gas mains near the roof.

The possibility of gas being turned into a boiler while a man is working inside is remote, as the precautions are simple and anyone inside can usually escape immediately or make his presence known. Some cases of injury that occurred to men working about the setting are described later.

PRECAUTIONS IN CLEANING THE BOILER OR SETTING.

LOCKING THE BURNER.

Before a gas-fired boiler is entered to clean the setting or combustion chamber of clinkered flue dust, the burner valve or slide should be locked shut by the foreman, water tender, or the cleaner. The person to whom the duty of locking the burner is delegated should retain the key from the time the burner is locked until the setting is cleaned, repair work by bricklayers finished, and all is in readiness to put the boiler in commission. Relatively few plants observe this precaution, as their experience has not demonstrated its necessity. Many plants consider it sufficient to attach a "Danger" sign. The value of using signs is not depreciated, but in boiler houses where valves are frequently manipulated on account of gas fluctuations or furnace stops, the use of locks is worth considering. The precaution of locking boiler gas burners may not seem so essential as to lock blow-off valves or stove burners, because at stoves there may be no indication of the reason for not turning the valve on, whereas the blackness of the combustion chamber in itself is a sign to experienced men not to turn gas into a boiler. Because of the haste with which the work is done at times, the inexperience of some firemen, and the fact that many types of burners have no space between the burner nose and the frame through which it projects into the combustion chamber, it is believed that at many boiler houses provision for locking burners and valves is justified. At least one instance of "gassing" caused by lack of locks or sign is known. One of several firemen, on receiving a signal from the water tender to turn gas into a battery of boilers following a shutdown, opened a burner valve of a cold boiler in which two bricklayers were working. One of the bricklayers got out before being overcome and the other was rescued with no serious results from his experience. This near accident illustrates the possibility of a serious accident happening when locks are not provided.

PROVIDING AGAINST LEAKS.

Before allowing men to enter a boiler setting the foreman should see that any gas leaking from worn or poorly seated valves can not be drawn into the boiler setting through the burner opening or the firing and ash-pit doors. With the old type of gooseneck slide burner, which is racked back on a horizontal seat, there may be a

considerable leakage, if uncleaned dusty gas is used, up through the burner in proximity to the burner opening into the boiler setting, and also between the burner base and seat into the boiler house, possibly adjacent to the firing or ash-pit doors in the front of the boiler setting. Inasmuch as the nose of this type of burner is withdrawn from the setting when the burner is closed, the simplest and best way to stop any leaking gas from being drawn into the setting is to mud up the nose with clay and place a piece of sheet iron between the nose and the burner opening. Leaks about the seat should also be stopped with clay, both at the burner of the boiler being cleaned and at the burners of adjacent boilers. To those accustomed to work about boiler houses having little difficulty with dusty gas, the possibility of gas blowing from about eroded seats and necks of gas burners will seem of little consequence, but its importance is shown by the number of accidents from this cause. In one instance a boiler cleaner, entering the dust chambers before the leaks had been stopped, was fatally overcome: in another instance two laborers or cleaners were fatally overcome by gas drawn into the boiler from leaks about defective valves that were not thought to be of sufficient volume to cause any difficulty whatever.

One instance of fatal asphyxiation in a cold boiler was attributed to leakage of gas from another boiler through cracks in the partition wall, the boilers being set in batteries of two boilers each. This would seem possible only when the operating boiler was receiving excessive quantities of gas, some of which might conceivably be forced through fissures in the partition. Similar conditions are not infrequently seen when there is considerable puffing or emission of gas from about doors and cracks in the setting. Brick settings are rarely free from cracks. Such sources of accident are mentioned as an example of the surprisingly obscure ways in which serious accidents may happen, and are apparently a factor to be reckoned with in equipment designed as above.

Burners of the interior seated, valve type are increasingly common. At some plants the burner design provides only one means of cutting off the gas, which is by seating the bell or valve. The burner itself is, as a rule, fixed in position and can not be withdrawn from the setting, so that in event of uneven wear of valve or seat, or cutting by flue dust in the gas, there is a decided leakage of gas into the boiler setting. The preferable type of such valves is one in which two means of shutting off the gas next to the burner are provided—a slide valve or plate, and valve and seat as described above (fig. 4). Between the two is a handhole or door which may be opened when the boiler is off for cleaning, thus diverting any leakage of gas past the slide valve into the boiler house in preference to the boiler setting. Inasmuch as experience has demonstrated the propensity of metal

surface to cut when exposed to the abrasive action of flue dust, carrying upward of 5 per cent of coke dust, in gas the use of valves of the double-stop type rests on abundant reason. If the single-valve type of burner is used, the burner nose should preferably be so designed or changed that a sleeve may be provided that projects into the setting and, when the boiler is off for cleaning, can be pulled back to permit a plate being placed over the burner opening on the setting. Another method is to provide a hand hole or opening on the burner side of interior seating valves so that in case of a leaky valve, any escaping

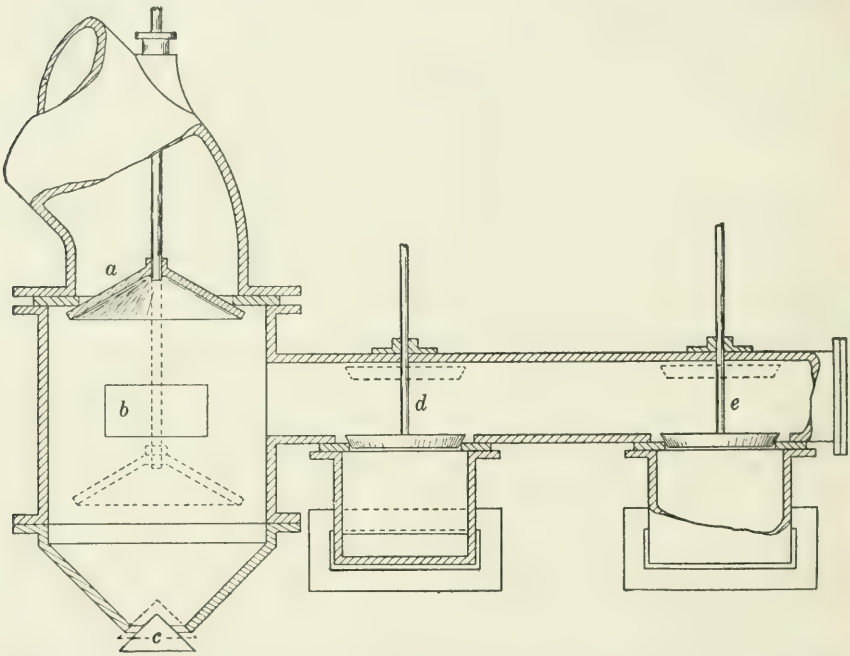


FIGURE 4.—Sketch showing general arrangement of valves for burner boilers. The solid lines show the position of the valves when the boiler is off for cleaning. Any gas leaking past *a* escapes through door *b* and bell *c*. Valves *d* and *e* prevent stack draft pulling gas into boiler setting. Dotted lines show valves open for operation of boiler.

gas may be diverted to the boiler room by plugging up the nose of the burner.

On a few very old boiler installations, where the burner is of the stationary type and the valve consists of an adjustable slide plate in the down leg, it is usual to find an opening in the down leg above the slide, plugged with a brick. Sand is run in on top of the slide when the boiler is off, then flue dust settles on top of the sand and makes an effective though inconvenient gas seal. What little gas leaks by this sand valve is easily taken care of by the stack draft. If, when the gas is turned off the boiler, its draft damper is left open and leaks about the burner are properly taken care of, there is no possi-

bility of gas lingering within the setting or being drawn in in dangerous quantities when the interior is cool enough to enter.

ENTERING THE BOILER SETTING.

At least two men should be assigned to work inside the combustion chamber or boiler setting. One man should remain outside, near the door, and should keep those inside in view always and be prepared to give any aid required in event of distress from gas. The men should "spell off" at frequent intervals. If the boiler has an individual stack, the draft damper should be kept wide open. If the boiler is connected to a stack common to two or more boilers, the damper should be opened sufficiently to induce a perceptible current of air through the boiler. Electric lights are preferable to hand torches. The foremen or water tenders, on being notified that the boiler is in readiness to be put on after cleaning, should see that all cleaners, masons, or others are out before unlocking the burner or removing danger signs from it.

ACCIDENTS FROM ASPHYXIATION OUTSIDE OF BOILERS.

Many cases are recorded of men being asphyxiated outside of the boiler setting from leaky gas equipment. In one of these instances a fireman sat down too near a leaky burner and was asphyxiated. Possibly he fell asleep, as the accident occurred during the night shift. Owing partly to poor lighting equipment and partly to lack of knowledge of his dangerous position he was not discovered until too late. The writer knows of three similar accidents. Also illustrative of the hazard from leaky burners is the example of a pipe fitter working on a steam-line fitting near the roof of a boiler house. He became gassed and fell to the top of the boiler setting, fracturing his arm. Another case in point is that of two boiler-house men who went on top of a boiler to turn steam into the main steam line. In so doing a gasket blew out, enveloping them in a cloud of steam. They retreated to the front of the boiler, where there were no steps or ladder, and by the time other men had closed the valve next the steam header and come to look for them one had been fatally overcome by gas from leaky burners beneath. Instances of asphyxia might be mentioned that were due to ignorance, such as turning the gas in without opening the draft damper; also cases purely accidental, such as a man being overcome by gas seeping up through the pavement from an underground main which later examination showed had been cracked by a gas explosion.

SAFEGUARDS.

It is obvious that keeping burners, valves, and gas-main equipment free from leaks is an elementary precaution in guarding

against asphyxia. If very dusty gas is used, leaks will inevitably develop, however, and to provide against unfortunate combinations of circumstances that may lead to serious injury or death, steps to and walks from top to top of a battery of boilers are warranted.

Exceptionally good illumination is to be desired, and a high roof with a ventilator at the peak is essential, particularly at plants where the boiler-house gas main is led inside the boiler house. Where such is the case and explosion doors are provided on the main, it rather commonly happens that the doors are continually leaking, and unless bolted down and their use discarded they are at times blown open. Even with a high roof, the gas will accumulate densely at such times. In one instance twelve men were overcome, two fatally, in attempting to close an explosion door blown open beneath a boiler-house roof by a slip. At this plant a water-seal valve is provided outside of the boiler house. It may be filled by opening a valve inside the boiler house, and the strictest instructions were in force that the water-seal valve be filled before attempting to repair explosion doors. More lately it was found advisable to provide oxygen breathing apparatus of the half-hour type. It is preferable to design so that the main is outside the boiler house, provided it is feasible to bring the burner down legs into the house.

The specifications of one company in regard to lighting and accessibility of boiler batteries are abstracted herewith:

A system of walks or runways shall be erected to give convenient access to overhead valves, also walks from boiler to boiler.

Wherever possible railed stairways are to be used in preference to ladders. When practicable, stairways shall be substituted for existing ladders.

Means of access shall be provided for overhead walks at both ends of each line of boilers, and on large plants one or two intermediate stairways are desirable.

Special attention shall be given to insuring good illumination throughout the boiler house. Unless the illumination is exceptionally good, it is advisable to have at least one light at each of the stairways leading to overhead, particularly at the upper end of the main stairways.

GAS MAINS.

It occasionally is necessary to enter some part of the gas-main system, beginning at the gas offtake at the furnace top and thence including downcomers, dust catchers, and gas mains to stoves and boilers, or to gas washers and thence to the stoves, boilers, and engines. At these places accidents have been caused by gas leaking down from the furnace top or from adjoining mains or equipment connected to furnaces in operation and containing gas under pressure; by traces or excessive amounts of gas remaining in the main on account of insufficient ventilation or ventilation of too brief duration; and by escape of residual gas held in dry flue dust, wet sludge, old brickwork of excessive porosity, and sand bulkheads.

Somewhat analogous, but of very little hazard, is work in hot-blast mains or bustle pipes when a furnace is off for repairs to them. Hot-blast mains and bustle pipes may, with blowpipes up and caps off, conceivably accumulate some carbon monoxide by leakage back from the furnace through tuyère openings plugged with clay and thence through the blowpipes and stocks back into the main. A fatal accident to a bricklayer engaged in repairs inside the main is the reason for mentioning this condition.

To put the main in condition for repair work or cleaning it is almost always necessary to blow cold air, by means of the mixer valve, through the main and out of the goosenecks or stocks in order to cool the brickwork as quickly as possible. This necessitates taking down the blowpipes, and therefore it will only be under very strange or unusual circumstances that the exigencies of the work do not necessitate taking down blowpipes, plugging the tuyères, and blowing through the main, apart from any considerations of safety, and thus making the system absolutely safe as regards leakage from the furnace or traces of gas remaining in the main by the gas having been drawn back in taking the furnace off and shutting down. It is evident that blowpipes should be left down until the work is done.

REPAIRING OFFTAKES AND DOWNCOMERS.

It has in the past been occasionally necessary to enter the nipples, or gas offtakes, and downcomer to make repairs to brickwork cut by dust or to clean out accumulations of dust deposited on flat tunnel heads and in downcomers of insufficient slope. The last condition may be said to be quite obsolete and done away with. The correction of this design is one of many instances which might be mentioned where the loss of tonnage from too frequent shutdowns and operating handicaps imposed by the choking of downcomers with dust have made imperative a rearrangement of plant equipment, quite apart from consideration of safety. In the period when this fault developed and was corrected there was a tacit acceptance of such hazards as one of the risks of furnace work. Every precaution was taken to avoid accident, but had the question of changing the design to eliminate the necessity for undertaking such work come up at that time, with no factor of tonnage gain or cost reduction entering in, it is probably doubtful whether it would have received much consideration. The same question during the past six years would have had every consideration given it.

Much change in design during the past few years has obviated considerable work in patching and relining the offtakes and downcomers. They have been increased in number and size, thus cutting down the velocity of gas; have been given the "castle construction," thus affording opportunity for a proportion of the dust to drop back

rather than to be carried over and impinge on and cut the brickwork; have had iron or steel wearing plates inserted at points where a change of direction tended to deflect the flow of gas and cause unusual wear from dust; and have been constructed without lining, as the predicted warping and erosion of the plate work did not develop, and pipe brick has been manufactured that withstands the cutting action of dust to an extent that gives a life of two or more linings of the furnace. Considerably stricter attention to screening coke at the coke ovens and stock house has also contributed to the life of offtake and downcomer linings by reducing to some extent the content of abrasive coke dust carried over in the gas.

It is still necessary in some instances to repair or patch the brickwork. There have been some fatal accidents in the past to men thus engaged. In two of these cases the indications are that because of failure to keep the gas lighted on top it accumulated in sufficient amount to drift down the downcomer. In the first case the bell was open and two manhole doors were open in the downcomer; in the second, the bells, bleeder, and explosion doors were open, and there was no door in the downcomer. The dust-catcher bells were open in both cases. In another instance a bricklayer was overcome and fell down through the downcomer.

Three methods of repairing downcomers that were noted by the writer are as follows:

1. The tuyères are tightly plugged with clay, and a double charge of fine dry ore is dumped on top of a coke blank. The bleeder, the gas-seal doors, and the farthermost gas burner are opened in the order mentioned, making a suction through the main. After this is done the big bell is lowered. If the gas does not light in the course of 10 minutes a piece of lighted waste is thrown in, and the gas lighted. The explosion doors are opened and a man stationed on top to see that the gas is kept lit. The experience here has been that there is always a vigorous draft up through the downcomer, and no trouble has been experienced with gas. After the gas has been lighted for about 10 minutes the doors and dust bell on the dust catcher are opened, and when the downcomer is cool enough to enter, the two doors on it are opened.

2. At the second plant the same procedure is followed; also a temporary 9-inch wall is built at the upper horizontal part of the gas offtake, when the repair work does not extend beyond that point.

3. At the third plant there are no explosion doors on the furnace or downcomer. In addition to opening the bells and bleeder and dust bell on the dust catcher, a 6-inch pipe from a small blower in the yard is extended up through to the working platform. The gas is not lighted, as the forced draft takes care of any gas that might tend to drift back, and the experience at this plant is that there is

no danger of top explosions of air and gas after such time as is necessary for cooling the downcomer has elapsed, though in a few instances slight explosions or "top cracks" have immediately followed taking the furnace off and opening the bells. Although this point has nothing to do with asphyxia, it may be said that such "top shots" have occurred elsewhere, even after 12 hours have elapsed, thus indicating the presence of gas, and it would seem better to light the gas.

The provision of working platforms is worthy of mention. The platforms provided are usually well constructed, built inside the

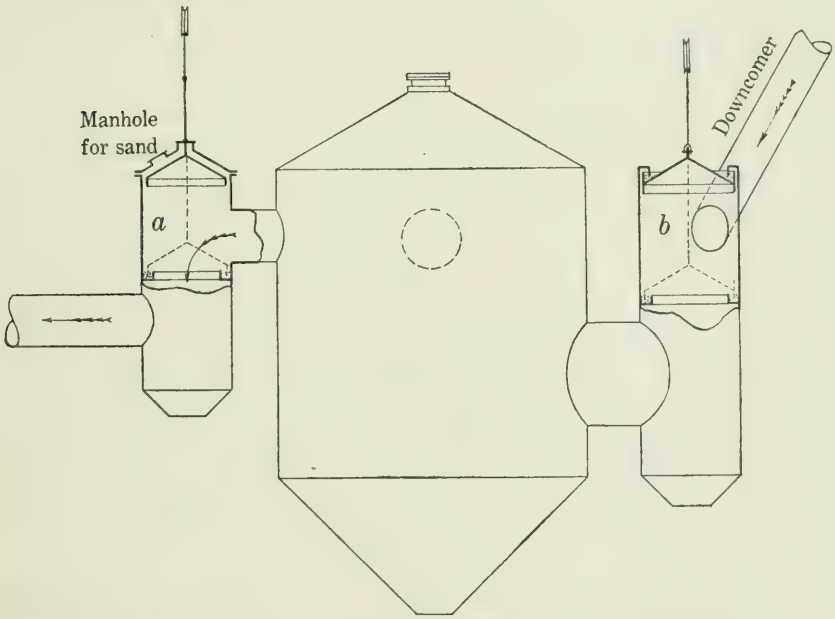


FIGURE 5.—Arrangement of dust catcher with Hamfeldt valve. At *a* full lines show normal position of valve when furnace is in operation; dotted lines show valve in closed position for entering gas line. At *b* the valve when open forms top of valve chamber; dotted lines show valve in closed position when dust catcher or gas mains must be entered, top of valve chamber open.

downcomer at 4 to 5 foot intervals, with substantial ladder approaches, either up through the dust catcher or from a manhole or explosion door on the downcomer.

REPAIRING DUST CATCHERS.

In repairing dust catchers men are subject to the same hazards from gas as in repairing downcomers, only to a less degree. The primary dust catcher of a series of catchers, as well as the usual single dust catcher, is, at all but three of the plants visited, without any valve between the furnace top and catcher. At certain plants, however, there is a Hamfeldt valve (fig. 5) at the base of the down-

comer just before it enters the dust catcher. Although the valve is heavy, difficult to handle, and requires additional equipment, it is a handy feature of gas-main equipment when work is undertaken inside the dust catcher, as it gives a sense and assurance of safety from any untoward happening or accident from gas from the furnace top.

REPAIRING MAINS.

Work in mains beyond the main dust catcher is, at plants having but one furnace, usually subject to a slight possibility of gas wandering into the main from the furnace top unless precautions are taken similar to those in undertaking work in downcomers or dust catchers. Isolated plants rarely have water-seal or other valves between the dust catcher and the mains, although at some plants gas washers are so arranged that they may be converted into water seals by raising the water level. Many plants having two or more furnaces are also deficient in valves at the dust catcher, the device for cutting the furnace off from others in operation being midway between the stove and boilers. At such plants, whenever it is necessary to go into the mains, the furnace is taken off and suitable steps taken to confine the gas to the furnace top, as described on page 39. It should be stated that although accidents in gas mains from asphyxiation may have been caused by gas descending from the furnace top to the mains, no such instance has been encountered; such accidents have evidently been due to other causes. The necessary precautions are so well understood and universally adopted, and so many openings may be provided between the top and the main, that percolation of gas to these points is only remotely possible.

At plants having two or more furnaces in operation, another condition of some hazard is found where the gas is taken from the dust catcher by two gas mains instead of by one. The general arrangement of valves for isolating gas mains is shown in figure 6. Each gas offtake is usually provided with a valve of some kind, either a mushroom, sand, slide, goggle, or water-seal valve. With such a layout sometimes the furnace is kept in operation while repairing gas mains, the gas being lead off by one main while the mains in which work is necessary are closed off by their valves.

THE GOGGLE VALVE.

When the valve is of the goggle, or solid and open disk, type connected by a bridgepiece which may be pivoted on a lug or bolt outside the main so that either the solid or the open disk may be swung into the main between the flanges and bolted to them, the main can be tightly and securely shut off in a few minutes. The trouble with the goggle valve is that warping or expansion of the mains may have

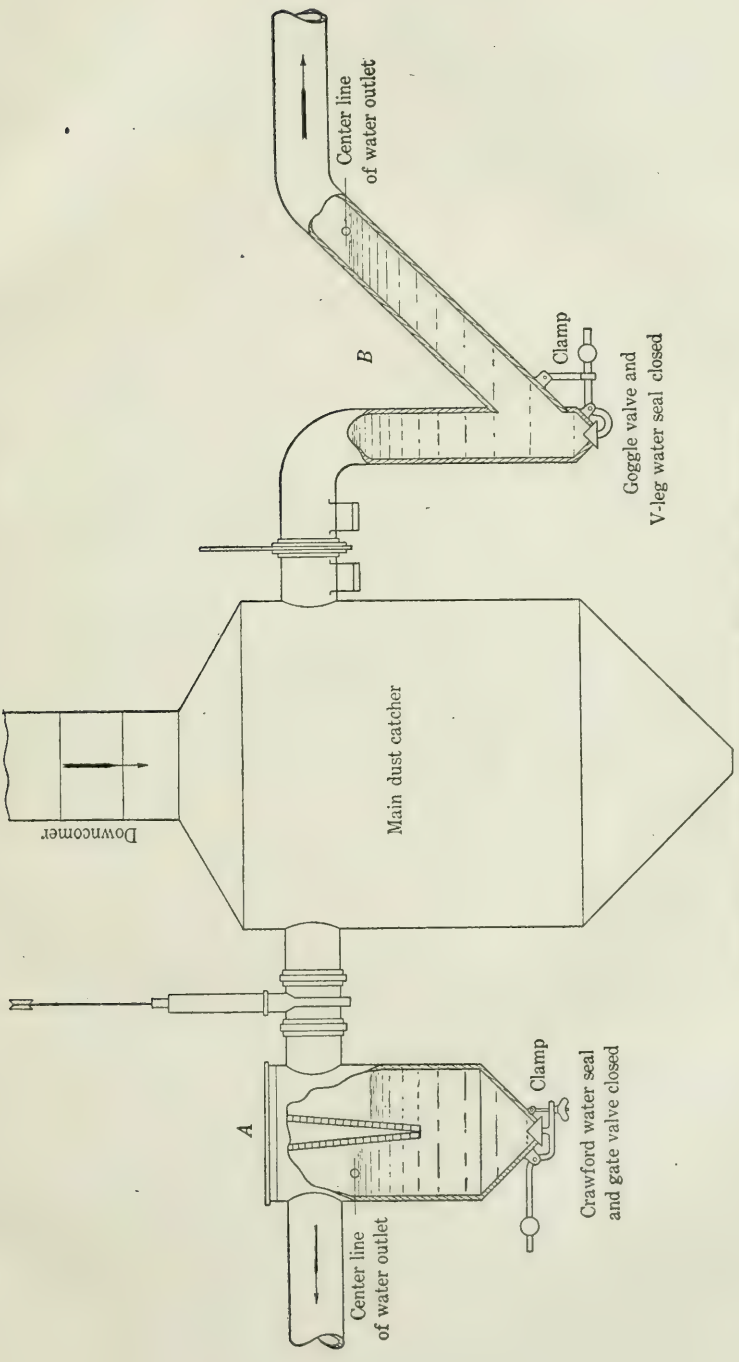


FIGURE 6.—Arrangement of valves for isolating gas mains.

wedged the valve so tightly in place that a considerable delay in opening the valve may be caused by the flanges having to be jammed apart with screw or ratchet jacks before the disk can be rotated. Another objection is that the men have to work in the presence of considerable quantities of gas in shutting or opening the valve when the flanges are spread, and it is not uncommon to find the rigger and millwright gang ill before the work is done.

In another design the valve is not rotated, but may be slid up and down between flanges, the solid disk being extended to have an open disk superimposed on it. The flanges are usually bolted, but in one plant they are held by jackscrews so attached that by screwing them the flanges may be forced apart or clamped in place. Such an arrangement is preferable in that it avoids delay, but is still objectionable in that it requires men to work near gas. The latter developments in this type of valve comprise bolts with opposite threads that screw into the two flanges. The bolthead, which is between the threaded ends, forms a small pinion engaged by a rack which may be moved up or down by a reducing gear from the ground. A block and fall being attached to the disk valve, the flanges may be forced apart, the valve raised or lowered, and the flanges clamped, all work being done on the ground away from gas. In another arrangement the flanges are forced apart by a cam and lever. The cam, being pivoted on one flange, forces the opposite flange away when the lever is moved, thus permitting the valve to be raised or lowered. The thrust of the gas main jams the flanges against the valve sufficiently hard to stop gas leaks. The flanges are held by bolts when the valve is in position.

INCLOSED SLIDE VALVES AND BELL VALVES.

No reliance can be placed in inclosed slide valves, in which the bottom and side flanges are inclosed to form a continuation of the main, or in inclosed bell valves resting on an annular seat, or in a trench containing sand or dust. These devices are useful when used with water-seal valves as a barrier to gas surges caused by slips or explosions, but will get leaky. In slide valves the seats will fill with dust and prevent perfect closure, and the same is true of bell valves, except the Hamfeldt type. The Hamfeldt valve as used on the furnace side of a dust catcher is usually so arranged that when dropped on its seat it opens the top of the valve body to the atmosphere. When this type of valve is used on the gas-main side of the dust catcher alone and without a water-seal valve in series with it, it is not satisfactory for some requirements of service. If it is desired to work in a gas main beyond the valve while the furnace is kept in operation, the valve is not tight enough to prevent gas leaks. Unless it is so arranged that upon closing it the gas pressure in the dust

catcher presses the valve against its seat, any sudden slip or gas surge may push the valve away from the seat. Such a valve arranged to lift up and engage its seat from beneath is unsatisfactory as regards preventing leakage or displacement when working in the main with the furnace in operation, gas being taken off through the opposite offtake on the dust catcher. If the valve is arranged to drop from above on its seat, the arrangement is unsatisfactory when repairs must be made inside the dust catcher, with gas from an adjacent furnace beneath the valve.

WATER-SEAL VALVES.

Water-seal valves, also known as Crawford valves and hydraulic seal valves, are the most effectual means of cutting gas off securely, entirely, and simply. Nevertheless, care in design is essential to assure the required degree of security. At some plants there are water-seal valves in which the depth of seal is insufficient to prevent gas from blowing through beneath the diaphragm or bend when under abnormally high pressure, and some are so shallow that when the furnace is in operation and gas passing through the valve it can not be filled with water on account of the gas blowing through beneath the diaphragm.

There are three general types of water-seal valves, as follows:

1. The gas main turns down into the top of a small auxiliary dust catcher, and extends down inside until the mouth is a suitable distance below the gas outlet of the dust catcher. By filling up the catcher with water, the furnace or main is sealed off. The disadvantage of this type is that if by reason of erosion the pipe is cut, as occasionally happens, there is no means of knowing that the sealing effect is lost until occasion arises to use the seal.

2. A **U** bend or **V** connection is made as shown at *B*, figure 6. This type is probably most liked, as it is of simple construction and there can not possibly be a leak through the valve as long as it is designed with a sufficient depth of seal, and all that is necessary is to watch that water is kept flowing through when it is in use.

3. The gas main is led into a vertical cylindrical tube, closed at the top and bottom, and in the center of which a diaphragm is placed, as is shown in *A*, figure 6. It is stated that the abrasion of dusty gas on this diaphragm, as the gas passes through it when it is not filled with water, may develop a leak that may not be detected and permit gas to leak across. This may be provided against, however, by making the diaphragm of **V** shape, as shown, and the top being open to the air, any gas leaking through the diaphragm may be diverted to the atmosphere.

The most usual depth of water seal is about 3 feet, the overflow being 12 inches below the gas-main bottom. This depth has been

found too shallow, and with U-type water seals a depth of 5 feet 6 inches has been noted. With a gas pressure of 15 inches the actual sealing effect is but 21 inches with a 3-foot seal. Gas pressures as high as 26 inches are found in regular operation, so that the margin of safety for a 3-foot seal is too small, as the water seal may be broken by a slip, and the seal once broken, gas may continue to blow through. The dust bells on water-seal valves should always be clamped shut when filled with water and in use, preferably with four L bolts.

WHERE VALVES ARE NEEDED.

As mentioned before, most single-furnace plants have no valves between the dust catcher and gas mains, and many plants having two or more furnaces do not. In either case, when a furnace has been shut down and, in case of two or more furnaces being in operation, its gas system has been isolated from those of other furnaces in operation, the chance of gas finding its way from the furnace top is small if the top is open, the gas lighted on top of the stock, and the dust catcher opened. More positive assurance may be obtained by having a water-seal, goggle, or disk valve, and the provision of such valve is amply warranted.

In event of a furnace having two gas mains leading from the dust catcher and it is desired to utilize one main to keep the furnace in operation while the other main is shut off for repairs, the general statement may be made that the practice is not safe unless there is a goggle valve, a disk valve, a slide valve with open flanges, or a water-seal valve with an auxiliary bell or slide valve to retard gas surges, or a water-seal valve back of which a brick wall has been built in the main. A water-seal valve alone or an inclosed slide or bell valve alone may prove insufficient.

A standing order at the works of one large company is as follows:

> When it is necessary for anyone to go into a gas washer, gas valve, or gas main connected directly to a furnace, for any purpose at any time, the Crawford valve must be sealed and guarded by a watchman who must not allow the seal to be broken. Also the bells and explosion doors must be opened and kept open. The gas must be ignited and kept burning, and a watchman must be stationed on top to see that the furnace top is kept open and the gas kept burning.

The above is a concise statement of safe practice, the reasons for which have been given in detail, and it is the practice most generally followed at large plants.

SELF-CLEANING MAINS.

It is becoming less and less the practice to enter gas mains to clean them. Many believe that the main will fill up to a certain

height, when the velocity of the gas will sweep along any additional dust and prevent further accumulation. Though this involves higher top pressure, they are unable to attribute to it any detrimental results other than occasional difficulty in changing tuyères. Cleaning the gas has not always obviated all requirement for cleaning the mains, and in some plants, where gas from tower washers deposits considerable wet sludge, there are provided small handholes, or stationary nozzles, or nozzles attached to a movable ball union permanently attached to the main and extending inside it. By means of high-pressure water connections the sludge is easily washed into down legs provided for this purpose. Gas mains have been made with frequent down legs, V-shaped pockets at close intervals (see Pl. VIII, *A*), "zigzag" construction, and left unlined, all of which requires less attention inside.

CLEARING MAINS OF GAS.

In event, however, of work being necessary inside, it is essential, after the main has been closed, to see to the ventilation. The information available indicates that the largest proportion of accidents from asphyxiation inside of mains has occurred from lack of ventilation, gas having been encountered lying stagnant in the main or escaping from wet sludge or dry dust.

For example, two laborers who were sent into a water-seal valve to clean it were overcome by gas; a bricklayer in a main was partly overcome by gas, retreated to the manhole by which he had entered, and fell through a bottom manhole; a force of 25 men was partly overcome on attempting to rescue men who had entered a main to clean it and were overcome by gas arising from the dry dust being stirred up; a bricklayer's helper was overcome while removing a sand bulkhead. There have been six other cases found, two of which were from leaking valves and four from residual gas and poor ventilation.

It is nearly always possible to ventilate a main by the draft of a stove, boiler, or by blowing or drafting out the main with a Theisen gas scrubber or fan, the manhole farthest from the source of draft being opened in order to sweep the main clear. It needs, then, only to keep in mind any dead gas pockets beyond the open manhole. If the pocket is deep the stagnant air and gas can be stirred up and displaced with a blast of compressed air or steam, which is usually available. Sometimes where a main is sealed at both ends, with no draft available, opening both the dust legs, or bottom manholes, and the top manholes will insure ventilation. In such a main movement of air is apt to be slow and caution is essential, and ample time should be allowed for the gas to escape. When there are only top manholes, it is imperative to go slowly. Diffusion

of gas out and air in is extremely slow in such places, and there can be no assurance that the main is clear and fit to enter unless positive means are employed to clear the gas out, such as a fan, exhauster, steam or air hose, or the air is tested for carbon monoxide.

It is in such ill-ventilated mains that men engaged in cleaning out wet or dry dust, removing bulkheads, or old brickwork have become asphyxiated. It is usually not only impracticable but impossible for men to wear heavy oxygen breathing apparatus in such cramped quarters and work, most of the heavy types being adapted more for mine work than for work in a 36-inch gas main. Certain types of breathing apparatus of half-hour capacity may be worn; they are inconvenient but less so than the task of taking an unconscious man back through 10 feet of main and out of an 18-inch manhole. In event of a lengthy job, it is probably most feasible to provide forced ventilation, such requirements are infrequent, but it is certainly worth while taking this precaution when there is reason to anticipate difficulty.

WETTING DOWN THE DUST.

In removing dust from a main, wetting the dust thoroughly will help to keep gas emission down to a minimum. This is difficult, as a thin skin or cake of mud tends to form and prevent the water penetrating very deeply, but with water under high pressure wetting can usually be done effectively. It is always essential, however, to expect gas even when this is done.

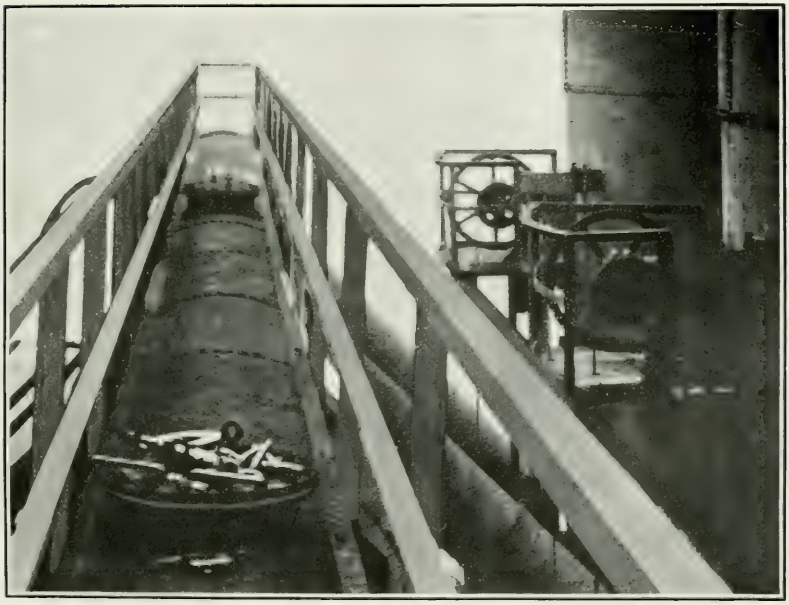
BULKHEADS.

Frequently a bulkhead consisting of two brick walls is built, the space between being filled with sand. Such a barrier, aside from checking a heavy gas surge because of the inertia of the barrier, is of little benefit, because gas filters through sand like a sponge, and when it becomes necessary to tear the bulkhead out, the workman is exposed to the accumulation of residual gas and gas of a particularly reeking odor productive of violent nausea, if not asphyxia. An 18-inch wall of vitrified brick laid in cement next to an open manhole on the side from which the gas comes, with a 4½-inch wall on the opposite side of the manhole is a more effectual protection and less difficult to remove.

MANHOLES.

The standard distance between manholes in gas mains appears to be approximately 20 to 24 feet. The standard size of manholes is 18 inches in diameter; there are a few smaller, many larger. If the diameter of the main permits, a 21-inch manhole is none too large. Twenty feet between centers of manholes should be the minimum in new construction, with down legs or bottom manholes spaced halfway between.

A. V-LEG SELF-CLEANING GAS MAIN.



B. RAILING ON HIGH GAS MAIN.

WALKS AND RAILINGS.

Lately many companies on their own initiative are providing walks and hand railings (see Pl. VIII, *B*) along all gas mains and railed platforms at gas valves. This will probably be standard equipment in the near future, as there is good reason for such installation.

GAS SCRUBBERS AND GAS-CLEANING BUILDINGS.

DANGER FROM GAS-CLEANING EQUIPMENT.

The introduction of gas-cleaning equipment brought with it new dangers from gas. The more thoroughly the gas is cleaned, the less is the chance of detecting it by sight or smell, and its use in gas engines has developed installations of cleaning equipment, the complexity of which together with the increased need of constant supervision and more frequent repair work is in contrast with the simple layout of mains to stoves and boilers using uncleaned gas. Three cases of fatal asphyxiation are known having occurred in gas-washer buildings, two occurring at night and one during the day. In another instance a painter engaged in whitewashing the interior of a gas-cleaning house fell from a ladder on account of being partially overcome. Two accidents, fatal in character, have happened to men working on repair work inside gas holders; two men have been fatally overcome while working on top of gas holders. Other fatal accidents have occurred inside gas-main equipment about gas-cleaning plants.

As brought out by accidents, dangers comprised in work on top of tower scrubbers in operation have developed and have been provided for in the course of the past six years. Those scrubbers having spray-distributing mechanism have developed leaks that may cause an accident. In one instance a millwright sent on top of a tower washer who was partly overcome with gas and apparently losing consciousness fell to the ground while attempting to descend from the top of a ladder. In a similar instance a repairman who was overcome on top, falling while coming down the ladder, caught his foot between the vertical strips of a safety cage ladder, just above a horizontal iron strap about the cage, and hung there until he was lowered with a block and tackle.

Inside of gas scrubbers there have been instances of fatal asphyxiation from gas emanating from sludge, wet surfaces, or pools of water saturated with gas, dead pockets of gas, or by insufficient ventilation or none at all. Four cases of the above nature have been noted. In one instance a laborer was overcome while cleaning out a ditch carrying discharge water from gas-cleaning equipment.

SAFEGUARDS.

RAILED STAIRS AND SAFETY LADDERS.

It may be said that with the exception of a number of washers of the Mullen type, most tower washers are equipped with substantial railed steps to the top, or with safety cage ladders. The exceptions are few, as the furnishing of such step or ladder equipment at tower washers is standard. The stairs or ladders are at most scrubbers arranged so as to give access to platforms or manhole doors at intermediate heights. These doors are used in adjusting or examining sprays or grids.

VENTILATION.

A manhole should be provided at the bottom of gas scrubbers in order to permit thorough ventilation from the base up and to permit of ready access in case of accident. Bottom manholes are not always provided.

A case in point illustrates the advantage of having such a door. A millwright sent into the bottom of a scrubber to examine the gas inlet, which had given trouble owing to a deposit of dust having cemented itself on the interior from splashes of water, was overcome with gas. No bottom manhole was available. The foreman lowered himself and attached a rope to the unconscious man, but the rope broke. The foreman also became partly overcome, and by the time another rope was brought and the two pulled out, it was too late to resuscitate the millwright.

It is essential to provide ample means of access and of ventilation. Sufficient ventilation is usually insured simply by opening the top and bottom manholes, but not always; a better method is to blow air in with compressed air or attach an exhauster to the isolated unit for two hours and entirely free it from gas, no one being allowed to enter the unit until this is done.

As an additional precaution, practiced at one plant, after the scrubber is isolated from the system by closing water-seal valves on both sides it is flushed out for 15 minutes by keeping the water spray on. This does away with the last possibility of gas from saturated water remaining in the scrubber. Such a procedure is especially necessary at Zschockke washers, where the lower end is immersed in a settling basin to form a seal. While men are in the scrubber, the exhaust is kept going to provide a current of fresh air, thus minimizing the danger due to breaking valves or seals.

SEALS AND VALVES.

In regard to seals and valves, it is necessary to have a valve on the inlet and discharge from each unit. Convenience and utility have dictated the employment of water-seal valves, hence working require-

ments have fulfilled the demands of safety. Where scrubbers are built close to the furnace, there is frequently, but not always, provided a mechanical valve, of the goggle or slide type, before the water seal on the furnace side, as shown in figure 7. This is to take care of surges of gas under high pressure and do away with the possibility of the water seals breaking.

The provision of such an additional valve is certainly warranted, though not essential when the scrubbers are connected with the

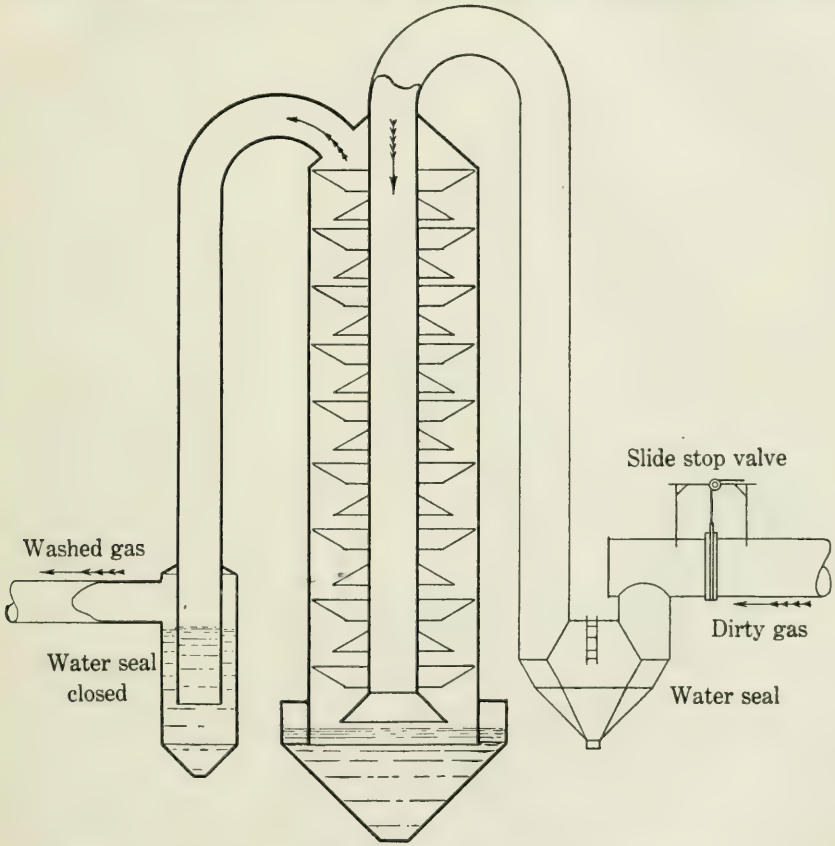


FIGURE 7.—Arrangement of baffle washer and water-seal valves on scrubber.

furnaces by a long system of mains, provided the water-seal valves have an effective seal of at least 30 inches of water with the gas against them. Thirty inches is arbitrary and can not be fixed as standard. It is mentioned as the minimum that is applicable to most installations and furnace practice.

The impinging type of washer, such as the Mullen or Moyer, is rarely provided with a water seal or other valve. As the washer is usually adjacent to the dust catcher, it can almost never be cleaned

unless the furnace is taken off. At some plants the downcomer leads directly to the washer. In undertaking repair work at this type of washer, the same precautions that should be observed in working in dust catchers or downcomers must be observed. But one case of asphyxia is known, and this apparently happened from poor preliminary ventilation. It seems as if it would be practicable to provide a bell valve at the gas inlet of the washer, where the gas is led from the dust catcher over to the washer. One company has installed such a valve, as shown in figure 8, and also made the washer easier

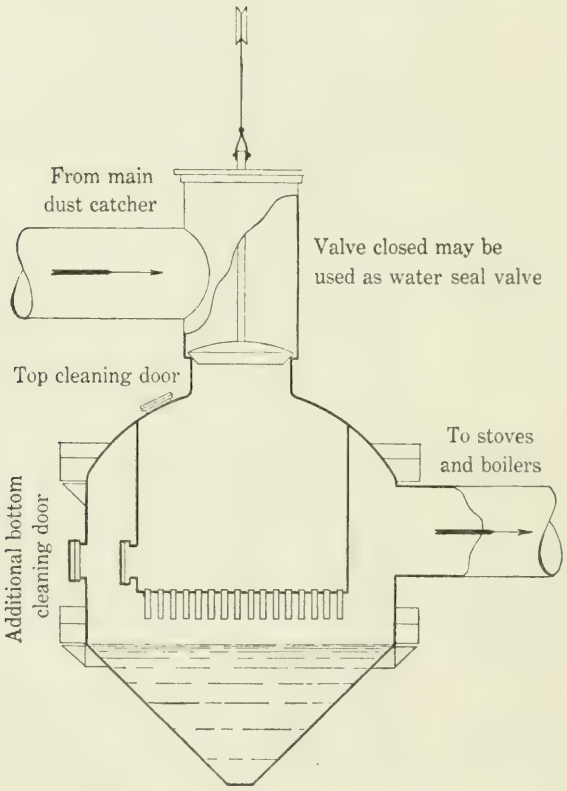


FIGURE 8.—Method of equipping Mullen washer with mushroom valve.

to enter by providing at the side a manhole door accessible from the lower platform. A few such washers are provided with an auxiliary main and with goggle valves by which the gas may be by-passed when it is desired to take the washer off. Considering that the washers of this type are somewhat subject to clogging up with dust from the gas, by reason of the cementing effect of vapor from the water, such changes represent a simple measure in convenience and security in handling this type of washer, and are improvements applicable at most establishments at no great expense.

The method of sealing a fan with water-seal valves is shown in figure 9.

SEPARATE MOTOR HOUSE.

At gas cleaning houses, one factor of hazard has been eliminated at more recent plants by erecting a separate building for the motors, rather than having the cleaner and motor inclosed in the same building. By this arrangement the motor building, as it is entirely separate from fans or Theisen washers, is free of gas leaking from stuffing boxes of rotary scrubbers or similar places, and also from trenches carrying discharge water.

EXHAUSTER.

In buildings which house cleaning equipment as well as motors, there is at some plants provided an exhauster to prevent contamina-

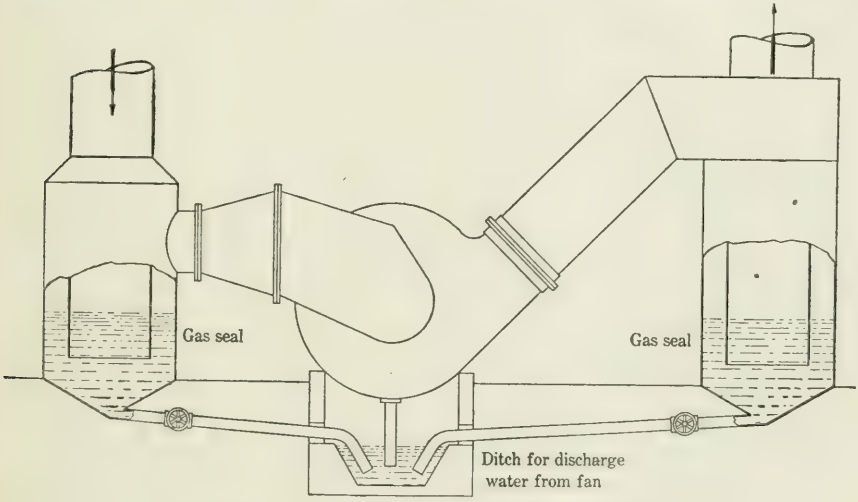


FIGURE 9.—Diagram of fan and water-seal valves.

tion and fouling of air by gas. This arrangement is preferable to providing openings in the bottom of doors or walls, which, in case of the gas being heavier than air, will allow any stray gas to escape.

SIGNAL ROOM.

A commendable feature of many gas houses is the provision of a separate room for gages, signals, and telephones, which is adequately sealed from the main building containing the gas equipment and is ventilated from outside the main building. Aside from any great hazard from excessive gas, such a room provides a working place, where it is necessary for the attendant to spend most of his time, in which he is not subject to the necessity of breathing an air vitiated by traces of carbon monoxide or odors from discharge waters in

ditches. Although escape of gas through the water inlet or discharge is everywhere prevented by traps in the overflow pipes or drains, the odor of gas is quite perceptible in many gas cleaning houses, and it may cause headache, indisposition, or at times prove sufficiently noxious to debar certain men from employment in the house. Others become accustomed to it, as previously indicated.

RULES TO PROTECT GAS-WASHER OPERATORS.

In some instances on account of excessive leakage or accumulative poisoning gas-washer operators have been found dead. This contingency is variously taken care of at present. One company requires two men on duty at night where only one is needed in the daytime. There is a revolving 24-hour chart at the main-entrance watchman's office, on which the operators register a record each half hour by closing a circuit from the washer house. In addition, the plant watchman or inside roundsman is required to report at the washer house every half hour and call up the watchman at the main office. There is a whistle at the gas-engine power house operated from the washer house. One blast (long or short) means "trouble; help wanted." The switch that operates the whistle is so arranged that the slightest movement will throw it in and it will remain in until pulled out. This provision was made so that if the operator is overcome by gas, the switch will remain in place until help comes.

PRECAUTIONS IN ENTERING INCLOSED PLACES.

Accidents in inclosed places such as gas mains or gas holders, are guarded against as at other mains. Water-seal valves are always provided and as Theisen washers or fans give a positive suction and discharge the mains can always be blown out or exhausted by running the Theisen washer before entering them; two hours is the standard practice. Gas holders may be similarly cleared of gas and they are provided with goggle or other valves by which they can be cut out of the system when the holder must be detached and the plant remain in operation.

GAS-ENGINE ROOMS.

The introduction of gas blowing and generator engines brought with it rather serious hazards from gas poisoning. These hazards were more marked in the earlier than in the present installations, but it may be said that gas-engine houses, even those which formerly were subject to too frequent accidents from gas, are at present in good condition, or are being put in good condition, as regards the danger from leakage of gas. That the early installation of gas engines presented unsatisfactory conditions is not a reproach to the

designers or to the companies installing them when it is remembered that for a considerable time there was difficulty after difficulty encountered in the design and working of large gas-engine parts. The frames, cylinders, castings, jacket walls, stuffing boxes, pistons, rods, and valves failed to meet the expectations of designers and manufacturers, and with these operating problems engaging their minds, it is no more surprising that the difficulties and dangers incident to the handling of the gas were not anticipated than that the mechanical deficiencies were not foreseen.

The causes of asphyxiation from gas at engines may be summed up as follows: Lack of positive means of closing the gas line leading from the clean-gas main to the mixing or inlet valve on the engine when the engine is shut down; taking the air required for the gas-air mixture from the engine basement instead of from outside; inadequate ventilation; lack of provision for sealing off the back pressure from common exhaust pits; and the escape of gas from sewers up into the basement.

PROVIDING AGAINST LEAKAGE FROM ENGINE.

A few fatalities have occurred in gas-engine basements where a metallic valve has been relied upon to stop the flow of gas. As it is very difficult to make such valves, usually of the gate type, sufficiently tight, gas continually escapes through the stop valve up to the mixing or inlet valve, and thence back through the gas-air manifold or air intake to the basement. As the gas is usually colorless and also odorless, it quickly accumulates in quantities sufficient to cause unconsciousness without any warning. To prevent this difficulty, water-seal valve or U tubes have been placed at practically all gas connections, both on old and new installations. At the older plants having air intakes in the basement, reliance is placed on this water seal, whereas in later installations the air is taken from outside the house through a pipe, exactly as the gas is brought from the clean-gas main, so that in event of a gas leak, however improbable, the gas is led back from the mixing valve to the outdoor air. In some installations of gas engines, the gas line is not brought in through the basement, but led in through the engine room, at the level of the inlet valve on top of the cylinders. Here, though no water seal may be provided at the gas-intake line of each engine, safety when the engine is shut down is insured by opening a manhole between the closed gate valve and engine, and any escaping gas is dissipated into the comparatively large space of the room and removed by the ventilation of the room rather than led up to the valves or cylinder parts where repair work may be in progress. Obviously, to open similar doors in a low-ceiling basement without forced ventilation would afford no relief.

VENTILATION OF GAS-ENGINE BASEMENTS ESSENTIAL.

Ventilation of gas-engine basements, or pits for the bed frame of the engine, where the basement is below the yard level is usually essential, for although intake-air and exhaust lines may be designed with the view of preventing the escape of gas, expansion or vibration may open flanges and permit gas leakage to an extent that would become dangerous if the gas was allowed to accumulate. Small basements are usually effectively ventilated by an exhaust fan set in a window at the yard level, the air being drawn down from the engine room above. Large basements are more adequately ventilated by forced ventilation, the air being taken from the outside and forced into the basement along a passageway at the side, escaping laterally at each engine foundation under the engine-room floor and thence up about the frame of the engine into the room and out through the roof ventilator. The contrast between the hot, close, unventilated basement and the cool, well-ventilated basement under forced ventilation is very marked as regards air conditions, and usually as regards upkeep and cleanliness.

In one instance a repairman was fatally overcome in a gas-engine basement by gas backing up from a sewer carrying water discharged from gas scrubbers. The cooling water from the engine jacket and piston discharged into this sewer also, and as the drain from the discharge pit to the sewer was not sealed or provided with a trap, the gas accumulated in fatally dangerous quantities. This arrangement is an unusual one, common to but one or two layouts, and at these traps are now provided.

No instances are known where asphyxia resulted from exhaust gases in gas-engine basements. In most installations two separate exhausts are used for each tandem engine and the gases are led directly from the exhaust port through a muffler to the atmosphere. In layouts where the exhaust gases are led into an underground channel common to two or more engines, there can be conceived conditions in which incompletely burned gas might leak back through exhaust valves. At such places water-seal valves are provided, as a rule, together with gate valves.

Many gas-engine houses are built with the floor of the house on the ground level, with the basement a cellar in every sense of the word. Preferable construction is, in the opinion of several furnace men, to have the basement floor nearly on the yard level, and the operating or engine room floor elevated. As these rooms are served by a crane, there is no loss in convenience in handling repairs from cars, and there is a certain gain in accessibility, ventilation, and convenience in the basement. At one plant, the light and ventilation in the engine basement are enhanced by leaving the space between the

frames of the twin tandem gas generators open. Except for a railed walk along the side of the bed plates, there is no floor, consequently men working in the basement are usually in sight.

The only precaution feasible in work about engine basements is to always assign two men to any work on or inspection of valves, pits, or parts. This ruling is in effect at every plant in the country. In addition, many keep oxygen breathing apparatus, and a less number keep resuscitating devices, at the engine room. Every plant reports that one or more men are on duty at the engine room who are instructed in artificial manual respiration or mechanical methods of resuscitation. The chief deficiency in gas-engine rooms is usually lack of forced ventilation, and this is confined to a few plants where the operators are familiar with the advisability of forced ventilation and for the most part are desirous of installing it.

FATAL ACCIDENT FROM EXHAUST GASES.

That the exhaust gases are sometimes sufficiently noxious to cause asphyxiation, in indicated by the death of two repairmen working at an elevation a little below the top of the exhaust pipe of a gas engine and about 30 feet from it. A gentle breeze carried enough of the exhaust gas to the working place to overcome both men. The local conditions were peculiar in that the exhaust pipe was in the valley of a saw-tooth roof on the engine room, and the top of the exhaust pipe was carried but little above the eaves, so that there was a combination of circumstances which is lacking at practically all other plants. The significance of the accident lies in the proof of the asphyxiating qualities of incompletely exploded or burned exhaust gases from gas engines, the need of carrying the exhaust piping several feet above the roof line so that the gases may be carried away by the wind, and the need of prudence when working on roofs or elevations near the place where the exhaust gases are discharged.

OTHER PLACES OF DANGER.

At every appliance that conveys or uses gas there is always danger that gas may be escaping in deadly quantities. Four cases are known where men working in open air but near escaping gas from valves or mains have been fatally overcome. Accidents of this character can be attributed in part to imprudence or ignorance on the part of the victims, and in part to lack of supervision, instruction, and precautions. Other places where men have been fatally asphyxiated are: Under dust catchers; in a locker shanty, located over a leaky underground gas line; in a lavatory of the trough type in which the flush water came from the stove, the line also carried discharge water from a water seal and discharged without intervening

traps into a sewer carrying discharge water from gas scrubbers; while working in an underground gas main which had been open for several days; and while working in a sewer leading from the hearth-jacket ditch to a sewer carrying water from gas scrubbers. The precautions are obvious in each case, and these accidents suggest that asphyxiation may occur in most unexpected and improbable ways.

GENERAL PRECAUTIONS.

No attempt has been made to present accidents from asphyxia statistically or to give them undue significance. The instances of asphyxia described herein have been noted to substantiate general statements advanced, and in each case they are authentic. Those unfamiliar with furnace work may have gained the impression from the previous pages of this paper that asphyxiation by furnace gas causes a great number of accidents, which is not true. In discussing asphyxiation in detail considerable stress has been placed on types and causes of accident, which may have given an incorrect idea to those unacquainted with furnace work. Of the fatal accidents at blast-furnace plants approximately 14 per cent, and of nonfatal accidents but 4 per cent, are caused by asphyxiation. The average time lost per accident from all nonfatal accidents is approximately 5 days, and from asphyxia alone is less than 2 days. Furnace gas is perhaps the most insidious danger to which the force is exposed, for although the worker encounters gas less frequently than a variety of other accident risks, it is likely to be most serious in consequences; that is, a larger proportion of accidents from asphyxiation result fatally than from other causes.

It is evident, on reviewing the circumstances of accidents at blast furnaces, that asphyxia prevention is dependent chiefly on the character and layout of plant equipment, upkeep of equipment, the extent of instruction, the planning and supervision of work in hazardous places, and the prudence of the men. Imprudence is variously ascribed to thoughtlessness, haste, ignorance, the inability of many workmen to satisfy themselves as to the point at which precaution ceases in the eyes of the foreman and loafing begins, and to a desire to do work with the least expense or delay. It is not just to dismiss the distribution of responsibility for accidents by attributing them to neglect or imprudence of workmen. Similarly, the proportion of accidents attributable to trade risk can not be determined without analysis of the character and upkeep of the plant equipment. The various types of causes have been discussed in this paper, with concrete examples and the general precautions to be taken. As regards specific remedies at any individual plant, a more practicable procedure will suggest itself, once the cause has been pointed out, than

is possible by a discussion of procedure to fit every condition of various plants.

Experience has shown that it is impossible for a man to breath a gaseous atmosphere for any length of time without being affected or overcome by the gas. The safest way is to make a rule that, except in cases of extreme emergency when lives are in danger or a serious accident must be averted, one must not enter a gaseous atmosphere. When conditions demand that a certain hazard be faced in order to avoid a greater hazard, as is sometimes the case at a furnace plant, the decision must rest on the superintendent and foreman.

METHODS OF CARRYING ON HAZARDOUS WORK.

A statement of the manner of planning dangerous work as carried out by various companies may be suggestive.

To take care of all contingencies introduced by various causes, all work in which there may be any possibility of "gassing" and in which a number of men are employed is personally supervised by a foreman. Such work is done by men acquainted with the nature and danger of the work and casual labor is avoided. Provision is made to render prompt aid in case anyone is overcome, and a respiratory apparatus is kept near by. Wherever possible, a belt and life line is attached to each man and tended by sufficient men to be able to pull anyone out who may be overcome, although it is sometimes difficult or impossible to carry out rescue work without entering pipes, scrubbers, or other places. The work is always carried out in shifts, the shorter the interval consistent with practicability the better. For working in atmospheres where gas is barely perceptible, one plant uses two shifts that change every 15 minutes. Breathing apparatus which often may be used to carry out work or to rescue men from a gaseous atmosphere is described in Technical Paper 82.[a]

These are used by a great many concerns, and as it is usually necessary to enter pipes or other inclosed places to rescue a man overcome, they should be kept near the place of work, even if they can not be used continually.

One large plant has the following equipment:

Gas-engine power house.—Two helmets and machines complete, with spare oxygen and potash cartridges.

Gas blowers.—One helmet and machine complete, with spare oxygen tank and potash cartridges.

Theisen washer.—One helmet and machine complete, with spare oxygen tanks and potash cartridges.

Emergency hospital.—One portable resuscitating apparatus, with spare oxygen tanks; one breathing mask with one large and three small oxygen tanks.

Laboratory.—One large tank of oxygen.

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[a] Henderson, Yandell, and Paul, J. W., Oxygen mine-rescue apparatus and pyhsiological effects on users: Tech. Paper 82, Bureau of Mines, 1916. In press.

Total.—Four helmets and apparatus, 1 rescuscitating apparatus, 34 small tanks of oxygen, 2 large tanks of oxygen.

Another company keeps large two-hour oxygen breathing apparatus and resuscitating apparatus at the plant office and on the plant ambulance, and also has three small half-hour apparatus, which are of greater utility about the Spiegel furnaces than the large two-hour apparatus.

Routine work that takes men into somewhat remote places of hazard is so arranged that there will be a record and systematic observation of their movement kept, as for instance, reporting to a foreman before going on top of a furnace or into a gas-engine basement and signaling and shouting to the foreman every ten minutes; in default of the signal, the foreman is obliged to go himself to the working place and see if the men are all right.

Perhaps there is greater reason at furnace plants than elsewhere not to employ men of intemperate habits or to permit a man to work while under the influence of liquor. Such men are only partly awake after the stimulating effect of the liquor wears off, can not apprehend the significance or danger of drowsiness, and may much more easily fall victims to asphyxia, especially as they are apt to hide in some out of the way place and sleep.

Every man engaged in duties that take him into frequent or occasional places of hazard from gas should be instructed about the danger, and should clearly understand that he must not take any chances, and that in case of uncertainty he should obtain orders to do the work, whether routine or special.

There are certain places to which access should be denied. The gas-cleaning house should be one. As regards gas-engine rooms and boiler houses, men should be prohibited from entering them if the equipment is leaky, but if it is not, such a prohibition is not necessary as far as considerations of asphyxiation are concerned.

THE USE OF DANGER SIGNS.

Danger signs are useful when placed at places of very definite hazard, but if used too liberally or promiscuously, they defeat their object. In practice they are used at the stairways to the top of the furnace and stoves, at ladders or stairs leading to the bustle pipe or galleries about the furnace, at the entrances to gas-engine rooms or engine basements, at gas-cleaning houses, at boiler-house entrances, at steps to the tops of boilers, in the boiler room as a warning against entering a boiler before notifying the foreman, and for general warnings at the plant entrance and about the plant. As a means of education, such signs are useful, but as a means of warning at especially dangerous places, they do not take the place of instruction. Signs

should be placed at entrances to gas-engine basements and at steps to furnace tops, further posting of signs must rest on the discretion of the superintendent. Any reliance on signs is misplaced, however, unless such warning is backed up by personal instruction, repeated as often as necessary, and personal supervision of work to the greatest possible extent.

TREATMENT FOR GAS POISONING.

Former treatment of asphyxia included such remedies as burying the unconscious or badly gassed man in sand, to "draw the gas out," giving the victim drafts of strong vinegar, putting blistering mustard plasters on the chest and back, cold affusions, slight electric shock, or slapping to "keep him awake." Those who recovered from severe cases of asphyxia did not, it is safe to say, do so by virtue of these measures.

Measures that have been recommended and tried with varying success by physicians include subcutaceous injection of camphor or strychnine, also alkaline salt infusions. These treatments are in the province of medical men and no data has been obtained as to their efficiency, nor can any recommendations be made as to the advisability of their use. They should, obviously, be attempted only by plant physicians or surgeons. Many physicians prescribe certain drugs to mitigate the headache resulting from moderate inhalation of gas.

Treatment that has been repeatedly demonstrated to be efficient in resuscitation from carbon-monoxide poisoning is described in Miners' Circular 23,[a] which may be obtained free by applying to the Director, Bureau of Mines, Washington, D. C. The information is of value in resuscitation of men severely gassed, and this paper should be supplemented by the circular named. The procedure in administering artificial respiration is as follows:

TREATMENT FOR SUFFOCATION AND ASPHYXIATION.

Suffocation or asphyxiation may be caused either by something that blocks the windpipe and prevents air from entering the lungs, or by the inhalation of gas that acts as a poison itself or prevents the air from entering the lungs.

If a man is overcome by bad air, move him to fresh air as quickly as possible, then loosen his clothing, place him face downward on a blanket or coat spread on the floor. One of his hands should be held straight out beyond his head; the other placed under his head. His head should be turned to one side and his tongue pulled forward,

[a] Lynott, W. A., and Harrington, D., and others, Elementary first aid for the miner: Miners' Circular 23, Bureau of Mines, 1916, 24 pp.

any tobacco, gum, false teeth, or the like, being removed from his mouth. Put a folded jumper or coat under the lower part of his chest if he is thin, straddle him on your knees, facing his head (see fig. 10), with your knees a little below his hips; then with fingers

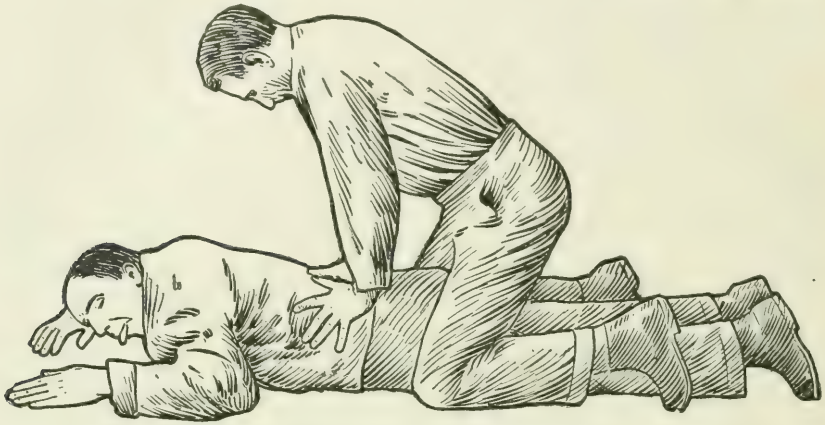

FIGURE 10.—Schaefer method of artificial respiration. Expiration.

outstretched place your hands at the lower part of his ribs with your thumbs nearly joining; then press downward and inward; then take pressure off slowly, keeping hands in place (see figs. 10 and 11); again with outstretched fingers as before, press downward and inward, and so on, about 16 to 20 times every minute. Keep this

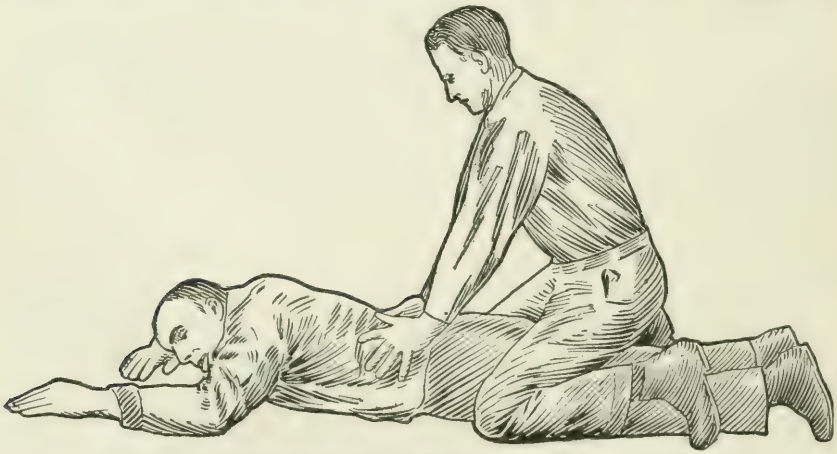

FIGURE 11.—Schaefer method of artificial respiration. Inspiration.

up for at least three hours if he does not start to breathe sooner. When he starts to breathe, keep him warm by covering with coats, jumpers, blankets, etc., or with hot-water bottles, but do not give brandy, whisky, coffee, or any other food or drink, unless he is able to talk and drink, then give one teaspoonful of aromatic spirits of

ammonia in a half a glass of water or hot coffee slowly. Do not place against the skin any hot article that might burn it. Place a thick blanket or cloth over the skin and be sure that you can hold the article in your own hand without burning it. When he starts to breathe, try to make him vomit by tickling the back of his throat or by putting your finger down his throat. Never attempt to give an unconscious man anything to drink, as the liquid will choke him.

USE OF RESUSCITATION DEVICES.

In all cases of insufficient respiration—that is, when the patient breathes regularly but very slowly—artificial respiration should not be given, but, if possible, nature should be allowed to restore the natural rate of breathing unaided.

The patient may with advantage be allowed to breathe pure oxygen, which may be supplied from a cylinder containing the gas under pressure; a reducing valve to lower the pressure, and a breathing bag with connecting tubes, face mask, and inspiratory and expiratory valves being used. The oxygen may be supplied by an oxygen generator; if this be done, no reducing valve will be necessary.

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